SUPPORTING TIMELY HA/DR DECISIONS THROUGH GEOINT AND GIS TOOLS

A Monograph

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AY 2014-001

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
22-05-2014	SAMS Monograph	June 2013 – May 2014

4. TITLE AND SUBTITLE
Supporting Timing HA/DR Decisions through GEOINT and GIS Tools

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Major Joseph E. Monaco, United States Air Force

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
School of Advanced Military Studies (SAMS)
250 Gibbon Ave
Fort Leavenworth, KS 66027-2301

8. PERFORMING ORG REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S Army Command and General Staff College
731 McClellan Avenue
Fort Leavenworth, KS 66027-2301

10. SPONSOR/MONITOR'S ACRONYM(S)
CGSC

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for Public Release; Distribution is Unlimited

13. SUPPLEMENTARY NOTES
N/A

14. ABSTRACT
Geospatial intelligence (GEOINT) evolved rapidly after the mid-1990s because of advances in technology. Joint doctrine attempted to respond to the advances in technology and the growing power of geographical information system (GIS) tools. However, the doctrine changes did not address the planning requirements for GIS. Planners need guidance of what to specify for the GIS analyst to exploit GEOINT. Exploiting GEOINT supports timely and accurate decision-making across the range of military operations. To determine specific guidance for planners, the research first needed to identify common operational decisions that require GEOINT support.

Faced with a large number of operational missions, the research narrowed to Humanitarian Assistance/Disaster Relief (HA/DR). The research further narrowed to HA/DR operations that respond to natural disasters, specifically earthquakes, which drive complex environments. Key concepts of John Boyd helped conceptualize an approach to model time-critical decisions muddled by complexity. The research examined a specific earthquake event to determine the linkages between GEOINT support, timely decision-making, and human suffering. The 7.0-magnitude 2010 Haiti earthquake case study revealed the common operational decisions that require GEOINT support to aid survivors in the immediate aftermath. Haiti also identified factors that delayed HA/DR decision-making. However, Haiti's observations did not fully validate HA/DR requirements. Further validation required the comparison to a hypothetical disaster scenario that could require GEOINT support in future HA/DR operations. The selected scenario focused on a great earthquake affecting Juba, South Sudan.

15. SUBJECT TERMS
Timely decision-making, Geospatial intelligence (GEOINT), Geographical information systems (GIS) tools, Humanitarian Assistance/Disaster Relief (HA/DR), 2010 Haiti Earthquake, Big Data, Crowd-sourcing, Common Operational Picture (COP)

16. SECURITY CLASSIFICATION OF: (U)			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. PHONE NUMBER** *(include area code)*
(U)	(U)	(U)	N/A	64	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

MONOGRAPH APPROVAL

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Monograph Title: Supporting Timely Humanitarian Assistance/Disaster Relief (HA/DR) Decisions Through Geospatial Intelligence (GEOINT) and Geographical Information Systems (GIS) Tools

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The opinions and conclusions expressed herein are those of the student author, and do not necessarily represent the views of the US Army Command and General Staff College or any other government agency. (References to this study should include the foregoing statement.)

ABSTRACT

SUPPORTING TIMELY HA/DR DECISIONS THROUGH GEOINT AND GIS TOOLS, by Maj Joseph E. Monaco, US Air Force, 64 pages.

Geospatial intelligence (GEOINT) evolved rapidly after the mid-1990s because of advances in technology. Joint doctrine attempted to respond to the advances in technology and the growing power of geographical information system (GIS) tools. However, the doctrine changes did not address the planning requirements for GIS. Planners need guidance that enables them to specify requirements and parameters needed by GIS analysts to exploit GEOINT. Exploiting GEOINT supports timely and accurate decision-making across the range of military operations. To determine specific guidance for planners, the research first needed to identify common operational decisions that require GEOINT support.

Faced with a large number of operational missions, the research was narrowed to Humanitarian Assistance/Disaster Relief (HA/DR). The research further was limited to HA/DR operations that respond to natural disasters, specifically earthquakes. John Boyd's concepts helped conceptualize an approach to model time-critical decisions muddled by complexity. The research examined a specific earthquake event to determine the linkages between GEOINT support, timely decision-making, and human suffering. The 7.0-magnitude 2010 Haiti earthquake case study revealed the common operational decisions that require GEOINT support. The Haiti case study also identified factors that delayed HA/DR decision-making. However, Haiti's observations did not fully validate HA/DR requirements. Further validation required comparing a hypothetical disaster scenario with the Haiti experience to determine whether the Haiti lessons could be generalized. The selected scenario focused on a great earthquake near Juba, South Sudan. Using ArcGIS Desktop 10.2, the author populated a geodatabase with real-world GEOINT, designed GIS-based spatial analysis models, and fused the model outputs into a common operational picture (COP).

The research revealed three common operational decisions tied to logistics that emerge during HA/DR operations that require GEOINT. The decisions affect campsite selection, food distribution point (DP) selection, and landing zone (LZ) and drop zone (DZ) selection. These decisions must be accurate and occur within the first seventy-two hours after an earthquake. The decisions directly aid survivors while earning the population's support. The South Sudan scenario validated the utility of GEOINT and GIS tools in support of the common HA/DR decisions. The research also illuminated the instructions planners must communicate to GEOINT analysts to enable their work.

ACKNOWLEDGEMENTS

A special thanks to Kevin Boyer at the National Geospatial-Intelligence Agency (NGA) who provided me with over one hundred gigabytes of real-world Geospatial Intelligence Base for Contingency Operations (GIBCO) data for Haiti and South Sudan. Additionally, I could not have performed the necessary analysis for this project without the help of my brother, Michael Monaco, Lead Geospatial-Intelligence (GEOINT) Analyst, NGA Office of Targeting and Transnational Issues. Mike took time during and after his deployment to Iraq to teach me the tricks of the ArcGIS Spatial Analyst Extension. Finally, thank you to my lovely wife Marcie and our seven wonderful children for allowing me to pursue my goals with the Advanced Military Studies Program through many months of work on this monograph.

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ACRONYMS

AFI	Air Force Instruction
AOI	Area of Interest
APAN	All Partners Access Network
ATP	Army Techniques Publication
ATTP	Army Tactics and Techniques Publication
CIB®	Controlled Image Base
CDS	Container Delivery System
COD	Common Operational Dataset
COIN	Counterinsurgency
COP	Common Operational Picture
CRED	Center for Research on the Epidemiology of Disasters
DP	Distribution Point
DTED®	Digital Terrain Elevation Data
DZ	Drop Zone
EDP	Externally Displaced Person
ESRI	Environment Systems Research Institute
FM	Field Manual
FOD	Fundamental Operational Dataset
GEOINT	Geospatial Intelligence
GIBCO	Geospatial Intelligence Base for Contingency Operations
GIS	Geographical Information System
GPS	Global Positioning System
GRC	Geospatial Readiness Center
HA/DR	Humanitarian Assistance/Disaster Response
HLZ	Helicopter Landing Zone
HRTE/I	High Resolution Terrain Elevation/Information

IASC	Inter-Agency Standing Committee
IC	International Community
IDP	Internally Displaced Person
ISR	Intelligence, Surveillance, and Reconnaissance
JP	Joint Publication
JTF	Joint Task Force
LIDAR	Light Detection and Ranging or Light/Radar
LZ	Landing Zone
NEO	Non-combatant Evacuation Operation
NGA	National Geospatial-Intelligence Agency
OCHA	Office for the Coordination of Humanitarian Affairs
OUR	Operation Unified Response
PZ	Pickup Zone
SIPRNet	Secure Internet Protocol Router Network
SRTM	Shuttle Radar Topography Mission
TC	Training Circular
WARP	Web-Access and Retrieval Portal

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INTRODUCTION

The key is not to make quick decisions, but to make timely decisions.

—General Colin L. Powell, *My American Journey*

Geospatial intelligence (GEOINT) evolved rapidly after the mid-1990s while joint doctrine tried to keep pace. Advances in technology, tested in opportune missions, drove the rapid GEOINT growth. For example, low cost GPS receivers offered precision location information to more users. At the same time, new sensors and geographic information systems (GIS) led to high fidelity imagery and faster processing. The Space-based Shuttle Radar Topography Mission (SRTM) and the airborne Light Detection and Ranging (LIDAR) sensors mapped the earth's surface. Google's Keyhole® (later Earth®) became popular while ArcGIS Desktop became a single integrated software architecture. Planners embraced ArcGIS to process the growing quantity and quality of GEOINT data because GIS tools significantly improved planning for military operations. The advances in technology and the power of the GIS tools prompted changes in joint doctrine regarding GEOINT use. However, those changes largely addressed the technical requirements, not the planning requirements for GIS. The doctrine needs to address planning guidance because planners must specify for the GIS analyst the GEOINT products needed to support decision-making. What the doctrine needs is guidance that tells the planners how to exploit GEOINT.

The military has a very large number of operational missions and the analytical requirements are likely to vary between types of missions. Consequently, it is not possible to address all the GEOINT planning requirements. Instead of surveying the military planning needs the research focused on identifying key operational decisions for a single type of mission. The goal was to determine what important operational decisions are impoverished[1] absent GEOINT support. The research focused on Humanitarian Assistance/Disaster Relief (HA/DR) operations because recent military experience shows that HA/DR operations require GEOINT more than any other activity. Natural disasters[2] are inherently complex and their initial conditions fall completely outside the span of human control. Timely and accurate decisions during the natural disaster response will continue to challenge planners. Figure 1 shows the trends in natural disasters since 1990. These trends are certain to continue.

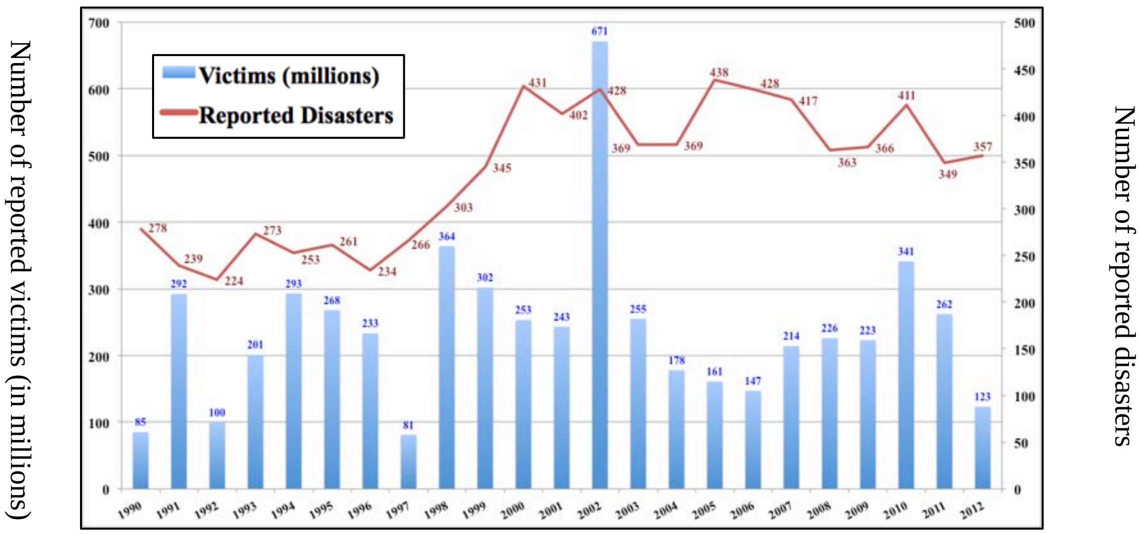

Figure 1. Trends in natural disaster occurrences and victims since 1990.

Source: Data from Debarati Guha-Sapir, Philippe Hoyois, and Regina Below, "Annual Disaster Statistical Review 2012: The Numbers and Trends" (Centre for Research on the Epidemiology of Disasters (CRED), August 2013), http://www.cred.be/sites/default/ files/ADSR_2012.pdf (accessed September 24, 2013), figure 1.

[1]A decision is impoverished if the decision-maker makes it without adequate information and accurate interpretation.

[2]Joint Chiefs of Staff, Joint Publication (JP) 3-29 *Foreign Humanitarian Assistance* (Washington, DC: Government Printing Office, January 3, 2014), GL-8. A natural disaster is an emergency situation posing significant danger to life and property that results from a natural cause.

The figure shows that hundreds of natural disasters occur each year and they affect millions of victims. Since 1990, the trend is that more natural disasters are reported around the world. Although the frequency is non-linear, the impact of natural disasters is widespread. No region of the world is immune from natural disaster spontaneity and planners will certainly need to respond to disasters during future HA/DR operations.

Although HA/DR operations comprise a single category in the broader mission category of defense support to civil authorities, the military responds to a variety of disasters and they too have different GEOINT analytical requirements. Thus, the research further narrowed to consider only responses to earthquakes. Since 1999, earthquakes have affected over one hundred million people and have led to over seven hundred thousand deaths. Therefore, improving the use of GEOINT during earthquake response may significantly reduce the amount of human suffering caused by those events. However, the goal of the research was not to identify how GEOINT can improve the HA/DR response generally but to identify the key operational decisions that must use geospatial analysis. To accomplish that it was necessary to investigate a specific earthquake event.

The case selected was the 2010 Haiti earthquake. The 7.0-magnitude earthquake affected over one million survivors. During the response, the responders relied heavily on GEOINT support and analysis. The case represents the greatest use of GIS tools in HA/DR to date. Thus, Haiti was the most opportune case to examine. The case reveals both the decisions supported by GEOINT and the types of analysis that supported those decisions. The Haiti case revealed that planners initially muddled their way to a timely response because speed was more important than efficiency. Examining the case revealed four concepts that show how GEOINT support eventually decreased response times. First, in the immediate aftermath of the earthquake, baseline data was missing and efforts to assess the situation were uncoordinated.[3] Because interagency efforts were uncoordinated, GEOINT data was hard to gather, manage, and share. Second, once data became available, planners had to rank order HA/DR requirements while simultaneously selecting the data[4] to be stored in GEOINT geodatabases[5]. Creating priorities for GEOINT support and determining which datasets would satisfy those requirements created additional delays. Third, planners chose parameters and used spatial analysis tools within GIS-based models to solve complex problems. Once analysts collected the data, they used map algebra and GIS-based models to quickly create products that ultimately improved decision-making.[6] Lastly, planners and aid workers required a common operational picture (COP) to filter and fuse the data amidst the changing geography.[7] The solution was a GIS-based COP to share data while enhancing interagency cooperation.[8] The Haiti study revealed planning lessons and illuminated the decisions that require GEOINT.

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[3]John Crowly and Jennifer Chang, *Disaster Relief 2.0: The Future of Information Sharing in Humanitarian Emergencies* (London, United Kingdom: UN Foundation & Vodafone Foundation Technology Partnership, 2011), 3, http://www.unocha.org/top-stories/all-stories/disaster-relief-20-future-information-sharing-humanitarian-emergencies (accessed August 6, 2013).

[4]Sanat Joshi, "Big Data: Putting Data to Productive Use," *InTech* 60, no. 3 (June 2013): 41, http://search.proquest.com/docview/1399521227 (accessed July 23, 2013). Data mining puts Big Data to use.

[5]A geodatabase is a geospatially-referenced dataset.

[6]Lin Feng-Tyan, "Many Sorted Algebraic Data Models for GIS," *Int. J. Geographical Information Science* 12, no. 8 (March 26, 1998): 765, http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.100.5921 (accessed August 5, 2013). Map algebra allows two or more raster layers of similar dimensions to produce a new raster layer using algebraic operations such as addition, subtraction, etc.

[7]LTG P. K. Keen, "Joint Task Force-Haiti Observations and Recommendations" (PowerPoint Presentation, Doral, FL, March 4, 2011).

[8]Environment Systems Research Institute, "GIS for Best Practices: Essays on Geography and GIS" (ESRI, February 2007), http://www.esri.com/library/bestpractices/essays-on-geography-gis.pdf (accessed October 9, 2013). According to ESRI, "a good GIS program is able to process geographic data from a variety of sources and integrate it."

The Haiti study revealed three common HA/DR logistical decisions that require GEOINT support.[9] The three decisions affect campsite selection, food distribution point (DP) selection, and landing zone (LZ) and drop zone (DZ) selection. First, GEOINT supports the identification of suitable campsites for survivors. Accurate campsite selection requires application of GIS tools. Second, GEOINT improves the design of the food distribution system. Planners use GIS tools to find optimal food DPs.[10] Third, GEOINT guides the selection of LZs and DZs necessary for safe supply delivery. Planners use GIS tools to remotely find and survey the suitability of LZs and DZs. However, examining the Haiti case and identifying the common decisions did not alone validate the requirement for GEOINT support in HA/DR.

To validate Haiti's lessons and the value of GEOINT it was necessary to develop a hypothetical scenario. The scenario needed to be based in a geographic location outside Haiti and prone to earthquakes. The purpose of the scenario was to test the data and analytical requirements observed in Haiti in another similar situation to determine whether the analytical requirements were independent of the conditions found in Haiti. The scenario selected focused on a great earthquake [11] with an epicenter one hundred miles south of Juba, South Sudan. Juba proved to be a good location because it is one of the fastest growing cities in Africa and current GEOINT data there lags behind other areas.[12] Using ArcGIS Desktop, the researcher populated a geodatabase,

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[9]United States Southern Command, *Operation Unified Response (OUR) Haiti Relief Mission SOUTHCOM AAR*, After Action Report (Pensacola, FL: Naval Operational Medicine Lessons Learned Center, May 2010), 41, https://www.jllis.mil/nomi/speciality.cfm?disp=site.cfm&&ssiteid=227 (accessed July 3, 2013).

[10]Water aid is equally important in HA/DR. Water aid falls under food aid for this research.

[11]A great earthquake is >7.0-magnitude on the Richter or Moment Magnitude Scale.

[12]Richard Grant and Daniel Thompson, "The Development Complex, Rural Economy and Urban-Spatial and Economic Development in Juba, South Sudan," *Local Economy* 28, no. 2 (March 1, 2013): 218-230, http://lec.sagepub.com/content/28/2/218 (accessed November 11, 2013).

ran GIS spatial analysis models, and compiled a COP for Juba.[13] The modeling requirements and parameters came from Haiti's lessons and the research applied GIS-tools to illustrate how GEOINT enhanced the common HA/DR decisions. The GIS-based models in the scenario found suitable campsites, food DPs, LZs and DZs. Validating these decisions also revealed the items planners must provide to the GEOINT analyst to enable their work. Thus, the research identified specific decisions during HA/DR operations that require GEOINT support and the information that planners must provide the geospatial analyst to obtain the required GEOINT products. These findings represent a first step toward improving doctrine for HA/DR planning.

HA/DR DECISION-MAKING

Timely and accurate HA/DR decisions manage complex problems while saving human lives, but support for these decisions does not arise naturally. Decisions do not arise naturally because the natural disaster environment is complex. There are two overarching challenges to timely and accurate HA/DR decision-making support. First, muddled decisions exist because complex HA/DR environments drive complex information environments. Joint Publication (JP) 3-29 *Foreign Humanitarian Assistance* highlights five characteristics of a natural disaster environment that ultimately drive information complexity in the first seventy-two hours:[14]

1. Many *[sic]* civilian causalities and populations besieged or displaced.
2. Serious political or conflict-related impediments to delivery of assistance.
3. Inability of people to pursue normal social, political, or economic activities.
4. High security risks for relief workers.

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[13]The National Geospatial-Intelligence Agency (NGA) provided 100 gigabytes of Geospatial Intelligence Base for Contingency Operations (GIBCO) data to enable realistic analysis and processing.

[14]JP 3-29 *Foreign Humanitarian Assistance*, III-4.

5. International and cross-border operations affected by diplomatic or political differences.

During the first seventy-two hours after a natural disaster, decision-makers require baseline information to assess conditions on the ground. Because of the information gaps and the timing required, JP 3-29 addresses a military commander's seventy-two hour authority for prompt action to save human lives.[15] Once the international community (IC) responds, the responders fill the information gaps rapidly with raw data that actually delays decision-making. The rush of raw data creates confusion by the overwhelming IC responders' confidence in the accuracy of the data. The decision-makers' response is slower because they must not only decide what to do but also what data is trustworthy. Verifying and storing data is the second challenge to timely and accurate decision-making support. Given a complex information environment spread across a large number of stakeholders, decision-making becomes more difficult while the time to make crucial decisions lengthens. According to JP 3-29, understanding the complex HA/DR operational environment requires a "broad, holistic view" because " . . . forces of nature, nonmilitary personnel, organizations, and systems combine to complicate joint force operations and influence the application of force choices."[16] Given that complexity will always exist, the theories of retired US Air Force Colonel John Boyd can help address HA/DR decision-making challenges in complex environments.

Decision-making challenges make more sense when looking at Boyd's key concepts that focus on the challenges to timely decisions in complex environments. Boyd argued that when faced with complexity, accurately linking the environment to decision-making actions becomes critically important because chaos is a natural state. Since chaos is a natural state, the planner will

[15]JP 3-29 *Foreign Humanitarian Assistance*, B-3. A military commander with assigned forces at or near the immediate scene of a foreign disaster may take prompt action to save human lives.

[16]Ibid., I-6.

always require an iterative process to quickly understand messy situations. Timely and accurate decisions in HA/DR require the planner, and ultimately the decision-maker, to continuously observe reality. Observations and actions must change, as Boyd stated, as reality itself appears to change.[17] At first glance, this appears to be a simple approach to decision-making. However, the implications become profound when examining the response to a massive urban earthquake where millions of human lives are at stake. A planner must understand current conditions while possessing capable tools to predict future conditions. In short, response during HA/DR requires real-time data and analytical tools to coexist in order to accurately react to current observations while predicting future conditions.

An effective and proven method for timely and accurate decisions is GEOINT. Near real-time GEOINT data used by GIS tools provides an effective means to process data into useful information for timely and accurate HA/DR decision-making. Planners must use GIS tools to filter, prioritize, model, and share information to support key decisions. Without GEOINT and GIS to support decisions, response leaders are more likely to worsen conditions by their actions, or even inaction.[18] Like other complex adaptive systems[19], there are positive and negative properties that result from HA/DR operations. As a remedy to the negative properties that emerge, Boyd offers two modeling frameworks to understand and support timely decisions: general-to-specific and specific-to-general.[20] In HA/DR, general-to-specific modeling is most appropriate because in essence, HA/DR are logistics-heavy operations that require breadth and

[17]John R. Boyd, “Destruction and Creation," September 3, 1976, 2, http://goalsys.com/books/documents/DESTRUCTION_AND_CREATION.pdf (accessed November 11, 2013).

[18]Firoz Verjee, *GIS Tutorial for Humanitarian Assistance* (Redlands, CA: ESRI Press, 2011), 3.

[19]Frans P. B. Osinga, *Science, Strategy and War: The Strategic Theory of John Boyd* (New York, NY: Routledge, 2007), 95. Complex adaptive systems are those that learn and adapt while in the midst of conflict. There are feedback and emergent properties from complex adaptive systems.

[20]Boyd, “Destruction and Creation,” 2.

depth.[21] Logistics require a holistic view from the start of the disaster because HA/DR focuses on the movement of people and resources. Natural disasters often disrupt and damage normal distribution networks, and through their reactions, humans themselves drive additional complexity. For example, increased movement by displaced persons overwhelms any undamaged transportation nodes and routes. Natural byproducts of the disruption and damage, fleeing population and trapped resources, produce an abundance of data for disaster responders to sort out. Therefore, HA/DR becomes difficult to manage without GEOINT since details cloud big-picture solutions.

One requirement for timely decisions is poorly addressed in doctrine. Doctrine does not address information management, or the organized flow and filtering of data to form a comprehensive picture of the environment. Linked to information management is the need to set priorities for information requirements; priorities drive Intelligence, Surveillance, and Reconnaissance (ISR) collection. Combining information priorities with ISR collection in accordance with Boyd's concept for general-to-specific information flow provides a holistic HA/DR system picture. For example, a decision-maker may feel the need to divert resources outside a badly damaged village if he focuses solely on the number of survivors in that village. However, if the decision-maker knew through GEOINT that the village is prone to mudslides he undoubtedly would seek a different location for campsites and food aid so survivors avoid a more dangerous situation. The best method by which to build a comprehensive HA/DR picture is GEOINT. The alternative to GEOINT support is poorly informed and less accurate logistical decisions that make complex HA/DR systems even more complex. Current doctrine, however, to

[21] *Operation Unified Response (OUR) Haiti Relief Mission SOUTHCOM AAR*, 41.

include the latest release of JP 3-29, does not directly link GEOINT support to better-informed HA/DR decisions and the need for better information management.[22]

Doctrine and after action reports (AARs) indirectly address analog and GEOINT-based solutions for the three common HA/DR decisions: campsite selection, food DP selection, LZ and DZ selection. Although these logistical decisions become more important when tied to HA/DR, it is important to highlight that their relationship to GEOINT support does not make them important. They are independently important. That is, all three decisions directly affect the lives of human survivors whether GEOINT is available or not. The question remains, how does GEOINT enhance the three common HA/DR decisions? The application of GEOINT reveals hidden spatial relationships that can have a decisive impact on the timing and effectiveness of the response.[23] The technology also provides automated methods for sharing critical information via a COP.[24] Doctrine and AARs indirectly touch on Boyd's recommendation that decision-makers repeatedly observe and orient based upon the measures of effectiveness (MOEs). The MOEs assess changes in the system's behavior, capabilities of those acting on the system (e.g., GIS planners), or the operational environment.[25]

A closer examination of each of the three common HA/DR decisions reveals their unique importance and why doctrine should explicitly link them to GEOINT support. Choosing three decisions does not imply that other decisions are not important in HA/DR. The three chosen decisions merely arise from doctrine and AARs as the most common. First, in the aftermath of any natural disaster, survivors displace and seek temporary shelter and food in campsites.

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[22]JP 3-29 *Foreign Humanitarian Assistance*, II-31. The doctrine does identify sector clusters that are similar to the UN cluster architecture. The clusters are health, protection, food security, emergency telecommunication, early recovery, education, sanitation/water/hygiene, logistics, nutrition, emergency shelter, and camp coordination/camp management.

[23]Verjee, *GIS Tutorial for Humanitarian Assistance*, 3.

[24]*Operation Unified Response (OUR) Haiti Relief Mission SOUTHCOM AAR*, 41.

[25]JP 3-29 *Foreign Humanitarian Assistance*, IV-5.

Survivors displace internally or move outside nearby existing borders.[26] In both cases, HA/DR planners seek suitable locations for campsites to shelter survivors and central sites from which to provide food and medical aid. Choosing a suitable location for campsites is crucial for several reasons. As previously highlighted, terrain and weather often endanger survivors displaced by earthquake activity. The Haiti earthquake killed over 222,570 people and displaced over one million residents.[27] Approximately thirty-seven thousand of the displaced population had moved to areas prone to landslides and flashfloods. Planners had to make rapid assessments to prevent a second wave of deaths from the likely flooding in the rainy season.[28] In addition, damaged buildings and remaining structures were prone to collapse, making urban areas unsafe and unlivable in Port-au-Prince. The undirected and unplanned movement of displaced survivors is an unfortunate reality in HA/DR and this is why selecting suitable campsites is an important decision.

Second, the need to distribute food to survivors emerges in natural disaster response. For example, earthquake damage displaces survivors and disrupts the normal food distribution networks. Increased population movement significantly overwhelms any undamaged transportation nodes and routes. In Haiti, the logistics jam at the Port-au-Prince airport and damage to seaports directly affected the delivery of food aid. While the logistics jam at the airport was unfortunate, Haiti was lucky that the earthquake did not damage the airport. Planners had to find ways to learn what airports, roads, and seaports were available to distribute critical supplies.

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[26] Joint Chiefs of Staff, JP 2-03 *Geospatial Intelligence Support to Joint Operations* (Washington, DC: Government Printing Office, October 31, 2012), B-2. Internally displaced persons (IDP) or externally displaced persons (EDP).

[27] "The International Disaster Database (EM-DAT)," *Centre for Research on the Epidemiology of Disasters - CRED*, last modified September 24, 2013, http://cred01.epid.ucl.ac.be:5317 (accessed September 24, 2013).

[28] Mario Ivan Ona, "NGA-FEMA Cooperation Embraces New Practices, Emerging Technologies," *National Geospatial-Intelligence Agency Pathfinder Magazine*, February 2012, 12.

The logistics of timely food distribution is always a major humanitarian need. Hence, selecting food DPs is one of the common and vital decisions a HA/DR planner must address.

Third, natural disasters damage and disrupt supply hubs that create a need for alternate or additional LZs and DZs to deliver supplies. The need to secure and expand lodgment in HA/DR operations depends on the terrain and extent of damage to primary ports.[29] This decision links to the previously discussed requirement to design a system for distributing food. However, the considerations for LZ and DZ selection differ from those directly concerned with food distribution. LZ sites require terrain free of obstacles suitable for safe rotary or fixed-wing operations. Aircraft deliver supplies into distribution networks during HA/DR either by air landing or by airdrop; forms of aerial delivery outlined in joint doctrine.[30] Given clogged transportation nodes and routes, planners must find alternate locations for aerial delivery and non-combatant evacuation operations (NEO). There are two challenges to making timely decisions for LZs and DZs: meeting minimum requirements for safe operations and remote surveying of data needed by pilots. There are several regulations that govern flight safety for rotary and fixed-wing aircraft. For instance, for heavy transport aircraft, DZs normally require a ground party to survey the terrain and complete a flight safety review.[31] Remote surveying of dynamic DZs is a new practice for supply delivery, made possible through high fidelity elevation data and imagery. The decision to remotely survey LZs and DZs is a requirement that will arise and which depends upon GEOINT for accuracy and interpretation.

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[29]LTG Frank G. Helmick, "Joint Forcible Entry" (PowerPoint Presentation, Fort Bragg, NC, September 15, 2010), 15.

[30]Joint Chiefs of Staff, JP 3-17 *Air Mobility Operations* (Washington, DC: Government Printing Office, September 30, 2013), IV-17.

[31]Department of the Air Force, Air Force Instruction (AFI) 13-217 *Drop Zone and Landing Zone Operations* (Washington, DC: Government Printing Office, May 10, 2007), 9.

At the time of this writing the delayed military response to Super Typhoon Haiyan in the Philippines reemphasized the importance of timely HA/DR logistical decisions. Record cyclone winds up to two hundred miles per hour and twenty-five foot tidal surges caused enough damage to affect ten million people. "Amid widespread suffering and reports of rising tensions on the ground, aid organizations and nations around the world raced to deliver aid to areas of the Philippines devastated by Super Typhoon Haiyan four days earlier."[32] In a radio interview, Marine Brigadier General Paul Kennedy, commander of Operation Damayan, outlined three priorities: shelter, aid, and LZs. Kennedy went on to describe that finding shelter for survivors, providing food and medical aid, and opening LZs suitable to C-130 aircraft must take place immediately to preserve human life in the HA/DR operations.[33] Typhoon Haiyan confirmed the need for timely decisions in a recent natural disaster, logistical decisions that require GEOINT support. While the Philippines presents a different operational environment than Haiti or South Sudan, Kennedy's remarks highlight that emergent tasks or HA/DR requirements, remain constant across all three environments.

EXAMINATION OF HA/DR DECISIONS IN HAITI

The analytical discussion of HA/DR key decisions and the need for GEOINT is borne out by the observations in the AARs from the 2010 Haiti earthquake. Examining the earthquake case showed that HA/DR decisions are inadequate without GEOINT support. There are three principle factors that delayed the key HA/DR decisions previously discussed absent GEOINT support. First, military planners during Operation Unified Response (OUR) muddled their way through the

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[32]Ivan Watson, Paula Hancocks, and Michael Pearson, "Typhoon Haiyan: Aid Delays Cause Rising Tensions in Philippines," World News, *CNN*, last modified November 12, 2013, http://www.cnn.com/2013/11/12/world/asia/typhoon-haiyan/index.html (accessed November 12, 2013).

[33]Mark Memmott, "Typhoon's Death Toll Likely Near 2,500, President Aquino Says," World News, *NPR*, last modified November 12, 2013, http://www.npr.org/blogs/ the two-way/2013/11/12/ 244695847/it-looks-like-a-50-mile-wide-tornado-hit-the-philippines (accessed November 12, 2013).

first seventy-two hours of the disaster response because there was no specific doctrine linking GEOINT support to decision-making. Planners rely on doctrine for guidance and the missing linkages between GEOINT and HA/DR decision-making are clear when reflecting on OUR. Second, the speed of the initial response, driven by decisions that supported logistics, was more important than efficiency. Time will always be the enemy in HA/DR, and in the case of displaced survivors in Haiti, planners initially struggled to develop timely solutions to address their needs. Lastly, Haiti had an exceptional information environment that drove data complexity. The unique information environment confused decision-makers, muddled interagency coordination, and hurt the overall unity of effort. While all three factors exist to some degree in other HA/DR cases, the Haiti case best showed their negative impact during the immediate response to a natural disaster.

Observations from the Haiti's AARs also revealed how GEOINT can mitigate the factors that cause delay in selecting campsites, food DPs, LZs and DZs. Two interconnected ways to leverage data are GIS-based models and GIS-based COPs. To portray the value gained by GEOINT, the study examined decision support at each stage of the disaster response. An unclassified GIS-based COP, although tardy, made HA/DR in Haiti successful by the end. Given the magnitude of the earthquake and number of affected people, Haiti's HA/DR operations were robust and well documented. Thus, Haiti's HA/DR lessons documented in the AARs permitted a comparison between the early analog products and the GIS-based products that later emerged. The case also highlighted the conceptual planning steps to transform GEOINT data into HA/DR decisions with GIS tools. The result was a six step conceptual GIS-based model for future HA/DR decision-making requiring GEOINT support.

Factors that Delayed Key Decisions

Missing Doctrine

The absence of doctrine linking GEOINT support to key logistical decisions helps explain why planners muddled their way through the first seventy-two hours of OUR. Even today, allied joint, US joint, and US army doctrine all address the GEOINT used in Haiti without explicitly discussing the importance of GEOINT in decision-making. Doctrine consistently defines GEOINT as " . . . the exploitation and analysis of imagery and geospatial information to describe, assess, and visually depict physical features geographically referenced activities on the Earth."[34] Doctrine also groups GEOINT into imagery, imagery intelligence, and geospatial information.[35] Regarding geospatial information, it is " . . . the foundation information on which all other information about the physical environment is referenced to form the common operational picture."[36] The information that GEOINT enables, best shared and portrayed through a GIS-based COP, is foundational to the HA/DR decision-making that took place during OUR. Further, appendix E provides a visual overview of the major categories of GEOINT data listed across doctrine. Apart from the general definitions and lists above, planning guidance for GEOINT support to timely decisions is scarce. Assessing the meaning of events through GEOINT enables a planner to observe reality within complex and dynamic HA/DR environments. Observation must take place before effective actions. In addition, lessons learned from OUR identify the first seventy-two hours as the most critical during the emergency response stage of the disaster risk management cycle.[37] Vital to observation during the emergency response stage is GEOINT. In Haiti, it took forty-eight hours for the Joint Task Force (JTF) to officially

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[34]Joint Chiefs of Staff, JP 1-02 *Dictionary of Military and Associated Terms* (Washington, DC: Government Printing Office, June 15, 2013), 149; Joint Publication (JP) 2-03 *Geospatial Intelligence Support to Joint Operations*, vii.

[35]JP 2-03 *Geospatial Intelligence Support to Joint Operations*. Title 10 of US Code, Section 467 provides these definitions.

[36]Department of the Army, Army Tactics, Techniques and Procedures (ATTP) 3-34.80 *Geospatial Engineering* (Washington, DC: Government Printing Office, January 29, 2010), 1-2.

[37]Christopher Piper, "Post-Earthquake Recovery in Haiti: The Challenges Ahead" (The Foundation for Development Cooperation, 2010), 6, http://www.microfinancegateway.org/p/site/m/template.rc/1.1.4554/ (accessed August 6, 2013).

stand up and another twenty-four hours for initial operational capability.[38] Planners can use GEOINT from remote locations while the JTF stands up. However, the planner's role was not intuitive in early 2010 doctrine. For the first three days following the earthquake, little information informed decision-making because GEOINT was underutilized.[39] Unfortunately, current doctrine still lacks the necessary linkage between GEOINT and decision-making immediately following a natural disaster.

Doctrine updates since 2010 only codified some of Haiti's lessons for future HA/DR planners. For example, Army Training Circular (TC) 2-22.7 *GEOINT Handbook*, addresses the HA/DR need for GEOINT support, but merely provides a checklist of capabilities.[40] Instead, a planner needs detailed guidance on how to use GEOINT with a GIS to support decision-making. In addition, current and draft versions of Army Techniques Publication (ATP) 2-22.7 show an extensive discussion of GEOINT as the "foundation for initial humanitarian assistance or disaster relief operations decisions." A metaphor best explains how ATP 2-22.7 falls short of its potential based off planner experiences in Haiti. If one thinks of the tools of an auto mechanic as wrenches and screwdrivers, vital to a planner working with GEOINT are GIS geo-processing tools.[41] ATP 2-22.7 lists sensor capabilities, standard and tailored products, and the capabilities of GEOINT. Think of this approach as a list of the parts of an automobile engine, such as the radiator and alternator, along with a summary of how the engine uses these parts to function. In a similar way,

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[38]United States Southern Command, "USSOUTHCOM and JTF-Haiti…Some Challenges and Considerations in Forming a Joint Task Force" (United States Southern Command, Joint Center for Operational Analysis, June 24, 2010), 4, https://www.pksoi.org/document_repository/doc_lib/HER_case_study_U_(24-Jun-10).pdf (accessed October 12, 2013).

[39]Ibid., 4.

[40]Department of the Army, Army Training Circular (TC) 2-22.7 *Geospatial Intelligence Handbook* (Washington, DC: Government Printing Office, February 2011), 6-4.

[41]David Smith and J.D. Overton, "Sharpening Your GIS Skills" (Seminar, Overland Park, KS, November 5, 2013), http://www.esri.com/events/seminars/fall-seminar-series/seminar-materials?WT.mc_id=EmailCampaignb17156 (accessed November 5, 2013). "GIS tools" and "geoprocessing tools" are used interchangeably throughout this paper.

ATP 2-22.7 lists the parts and functions of GEOINT, but relies on external agencies to perform the GIS analysis. To sum up, doctrine only outlines the first of three areas identified from the Haiti planning. The areas are GEOINT capabilities, what GIS analysis to request, and the basic spatial analysis planners can accomplish for decision support.

Post-Haiti doctrine insufficiently highlights advances in technology that allow GEOINT to integrate " . . . more sophisticated capabilities for visualization, analysis, and dissemination of fused views of the operational environment."[42] The problem is that the doctrine does not tell the planner how to exploit the capabilities. Army Tactics and Techniques Publication (ATTP) 3-34.80 *Geospatial Engineering* defines the GEOINT parts for a GIS, but does not provide a design to connect the parts.[43] Doctrine states that the potential of GEOINT lies in the integration of fused views for more comprehensive, tailored products. In Haiti, however, it took several days to reach the point where planners integrated enough GEOINT to support HA/DR decisions. During the delay, planners used analog products such as paper maps to generate knowledge about trends and patterns for awareness and decision-making. In short, while the technology existed in Haiti, processes to integrate GEOINT in a timely manner did not exist. Once again, when examining doctrine today, GEOINT integrative processes remain missing.

Additionally, planners in Haiti discovered a relationship between counterinsurgency (COIN) and stability principles and HA/DR operations that has not yet been addressed in doctrine. That is, COIN and stability principles from Field Manuals (FM) 3-24 and 3-07 also apply to HA/DR operations.[44] The enemy forces in an HA/DR operation are time and the elements, while the deciding factor of success is population support. Thus, a guiding principle in

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[42]JP 2-03 *Geospatial Intelligence Support to Joint Operations*, I-1.

[43]ATTP 3-34.80 *Geospatial Engineering*, B-2.

[44]MAJ William B. McKannay, "Lessons Learned from OUR," *Military Police*, 2011, http://go.galegroup.com/ps/i.do?id=GALE%7CA253536238&v=2.1&u=97mwrlib&it=r&p=AONE&sw=w&asid=ff88260ee39de27dae6a7d639362d59a (accessed October 13, 2013).

HA/DR response is that to effectively support the population you must first have their support. Garnering support comes through a rapid response, enabled by timely decisions, that addresses the greatest needs of the people at appropriate locations. Hence, like COIN, to mount an effective response requires a planner to understand the interconnected relationships within the complex HA/DR system.

Today the same potential for muddled planning seen in Haiti remains because doctrine remains undeveloped. Planners rely on doctrine, rather than lessons learned, when tasked to plan HA/DR operations. To be fair, the GEOINT Operations Process outlined in JP 2-03 provided the general methodology that eventually led to success in Haiti.[45] Then and now, however, the underlining deficiency is the failure to describe *who* performs *what* GIS analysis, and *how* a planner mitigates destabilizing factors in complex HA/DR environments. Doctrine shortfalls, however, is not the only obstacle to improved response. Two other factors caused planners to muddle their way to GIS-based solutions in Haiti. The two other contributing factors were the speed of the initial response and Haiti's unique information environment.

Speed over Efficiency

During the initial response to a natural disaster speed is more important than efficiency. Speed over efficiency as a principle involves both the rapid deployment of resources and the rapid distribution of those resources. In Haiti, planners did not fully apply the principle of speed over efficiency in the first seventy-two hours. Table 1 shows the 82nd Airborne Division's

[45]JP 2-03 *Geospatial Intelligence Support to Joint Operations*, IV–1. "GEOINT operations are the tasks, activities, and events to collect, manage, analyze, generate, visualize, and provide imagery, IMINT, and geospatial information necessary to support national and defense missions and international arrangements."

deployment into Haiti, much of which used inefficient[46] delivery means such as aerial delivery to achieve a more rapid deployment of resources.

Table 1. 82nd Airborne Division's Deployment: People, Equipment, and Supplies

Deployment: People, Equipment, and Supplies	
Passengers	3,553
Water (Gallons)	49,109
Class I (Meals Ready to Eat)	1,318,936
Vehicles and Trailers	518
Container Delivery System (CDS) Bundles	168

Source: Data from LTG Frank G. Helmick, "Joint Forcible Entry" (PowerPoint Presentation, Fort Bragg, NC, September 15, 2010), 15.

The 82nd's deployment is a positive example of employing speed over efficiency in HA/DR. Since HA/DR operations are logistics-heavy operations, the initial response must build sustainment capability from the start. While resources deployed quickly, those resources were not quickly distributed to survivors in the area of HA/DR operations. There are a couple reasons why this happened. First, the 82nd Airborne Corps joint planning capability did not arrive in Haiti until day three. Second, a Joint Logistics Operations Center was not established until day twelve. Faced with typical delays in joint logistics planning capability, the planners needed GEOINT and GIS analysis to immediately make decisions concerning distribution. However, there is no evidence that this happened before 15 January, three days after the earthquake.[47] The evidence does reveal a tendency to wait until the establishment of command and control structures and joint manning documents before taking action to distribute resources. The ability to move people,

[46]Aerial delivery is inefficient when compared to other domains (means) such as maritime (ships).

[47]"USSOUTHCOM and JTF-Haiti…Some Challenges and Considerations in Forming a Joint Task Force," 14.

equipment, and supplies not only to, but also within the affected area, determines whether the HA/DR operation is a success. Logistical speed not only garners public support, it minimizes loss of life. Thus, when establishing priorities for GEOINT support and applying GIS tools, the speed of initial response must be more important than the efficiency of the logistics system.[48] Once the HA/DR operation meets the basic survivor needs, then and only then should attention shift toward reducing the cost of prolonged sustainment through efficiency.

Untrained planners and missing baseline GEOINT products drove the lag in GIS analysis that ultimately delayed logistical decisions in Haiti. Planners in Haiti knew they needed GEOINT to augment on-ground assessments for initial responders, but lacked the knowledge and ability to create baseline GEOINT products on their own. The AARs from OUR revealed that US Southern Command (SOUTHCOM) commenced crisis action planning on the evening of 12 January, over twelve hours before the Joint Staff officially tasked them.[49] While staying ahead of the tasking contributed to success, it also showed the challenges of remote planning with a limited number of GEOINT-savvy personnel. "The most immediate tasks at hand were making estimates as to the extent of the damage and determining the DoD contribution to the whole-of-government response."[50] Even after the planners had obtained baseline GEOINT products, planning was delayed because the functionally organized staff mismanaged GIS analysis in the first twelve hours of planning. Later, once the JTF formed, the National-Geospatial Intelligence Agency (NGA) deployed an additional seven-person team to respond and provide GEOINT support. Prior to their arrival, the planners did not know how to use GIS to model time critical decisions. Initial

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[48]Joint Center for Operational Analysis, "Humanitarian Assistance and Disaster Relief Lessons Information Paper" (Joint Center for Operational Analysis, July 2011), https://www.pksoi.org/document_repository/doc_lib/JCOA_info_paper_ HADR_LL_(July2011).pdf (accessed October 12, 2013).

[49]"USSOUTHCOM and JTF-Haiti…Some Challenges and Considerations in Forming a Joint Task Force," 4.

[50]Ibid.

GEOINT collection focused first on post earthquake damage and then on the identification of LZs, pickup zones (PZs), and DZs for distribution of humanitarian aid. Other priorities were the assessment of transportation routes, determining the migration of displaced persons, and identifying locations for Internally Displaced Person (IDP) camps.[51] Although GEOINT data was readily available, planners did not exploit the datasets themselves nor communicate specific requirements to GIS analysts for them to analyze the data. A significant information gap emerged from the lack of baseline GEOINT products and lack of upfront GIS analysis: unsupported on-ground assessments needed for comparisons that ultimately support key HA/DR decisions.

After a few days in Haiti, baseline GEOINT products evolved into the vital backdrop needed for a comparison to near real-time GEOINT data. Once the JTF formed, planners gathered baseline products from the NGA, the National Reconnaissance Office, and the Geospatial Readiness Center for datasets and imagery.[52] Getting the data earlier would have permitted GIS-based modeling. The models would have provided the datasets to design an initial COP to support decision-making. Once a COP has been designed it is easy to update the COP by inserting new datasets. Adding the new datasets likewise updates the spatial analysis models because the GIS models embedded in the COP are already set up as shells. Instead, a four-person NGA team at the Corps headquarters at Fort Bragg, NC provided initial on-ground assessment support and stood by for future requirements from the planners. With a sense of urgency and baseline knowledge of the GEOINT Operations Process, planners can reduce the timeline. Despite the delay in Haiti, the GEOINT-based products that eventually emerged served an important purpose. The comparison

[51]Center for Army Lessons Learned, *Haiti Intelligence Observations*, After Action Report (Fort Leavenworth, KS: Center for Army Lessons Learned, March 11, 2010), 4.

[52]The GRC responded to assist in the HA/DR mission to Haiti, providing 12,600 maps (18x different maps sheets, 700x each), 70x DVD's containing imagery and digital maps, and four 500 Gigabyte hard-drives also containing imagery and digital maps. Another after action finding was that "GEOINT capabilities need to be task organized to deploy forward with any JTF headquarters, with consideration for adequate reach-back capability for additional support.

between the baseline products and near real-time GEOINT data made sense of the rapidly changing HA/DR environment, shaping intelligent options for decision-makers.

Today there are two ways for planners to obtain the baseline GEOINT data faster: Geospatial Intelligence Base for Contingency Operations (GIBCO) data and Cloud-based[53] GIS systems. Both have distinct advantages and disadvantages. First, the advantage of GIBCO is that it consolidates all unclassified imagery and datasets onto a series of DVDs. Appendix C shows the contents of a GIBCO DVD series. Datasets containing urban graphics, hydrographic charts, and elevation data are applicable to every HA/DR response. The disadvantage of GIBCO is that the data may not be current. Often the NGA datasets lag their commercial counterparts. Second, Cloud-based GIS systems, such as Google Earth® and ArcGIS Explorer®, provide high fidelity and current imagery as baseline layers and maps from the Cloud. However, accessing Cloud-based GIS data often requires a lot of bandwidth. While there are more sources today for baseline GEOINT products, planners in remote locations, typical in HA/DR, may not be able to harness all the data because of bandwidth limitations. Haiti was the ideal case to highlight the challenges that emerge from poor bandwidth within a rich humanitarian information environment.

Haiti's Unique Information Environment

Haiti's humanitarian information environment was the last factor that helps explain why planners muddled their way through the first seventy-two hours of the disaster response. Initially there was limited baseline GEOINT. After a large-scale disaster, however, there is a massive effort from multiple communities to collect and analyze large volumes of data. What made Haiti

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[53]Michael L. Binge, "ArcGIS Online and the Cloud," *Point of Beginning*, July 2012, http://go.galegroup.com/ps/i.do?id=GALE%7CA297717816&v=2.1&u=97mwrlib&it=r&p= ITOF&sw=w (accessed July 23, 2013).

unique was the crowd-sourcing[54] of information made possible through the Internet and mobile devices:

> The Haiti earthquake ushered in a new humanitarian information environment: one with unprecedented availability of raw data in all forms, the growing usage of new information communication technology (ICT), and the emergence of three loosely-connected humanitarian communities of interest . . . all three communities collected, shared, and acted upon enormous amounts of digital information made available on a variety of web portals, platforms, and new social networking media, such as Short Message Service (SMS) feeds, Twitter, Facebook, etc.[55]

Thus, even immediately after the earthquake, the environment became rich with information, thanks to three humanitarian communities of interest. The communities were the US Government, the UN and IC, and a new group comprised of virtually connected academics, humanitarians, corporate foundations, and ICT professionals. The communities as a whole produced large amounts of rich information, but the unfortunate reality is that there were delays in using that information.

Having large amounts of rich information does not naturally inform decisions. Having baseline information for future comparison is just as important. In Haiti, damage assessments required GEOINT data and imagery from before the disaster. Post disaster GEOINT collection enables damage assessments. These assessments inform decisions. Before the earthquake, the Government of Haiti's National Center for Geospatial Information (CNIGS) had one of the most complete GEOINT collections in the region. Through a commitment to advance geospatial information for sustainable development and natural hazard mitigation, the US Government and

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[54]Merriam Webster Dictionary, "Crowdsourcing--Definition," last modified 2006, http://www.merriam-webster.com/dictionary/crowdsourcing (accessed November 15, 2013). Crowd-sourcing is the practice of obtaining needed services, ideas, or content by soliciting contributions from a large group of people and especially from the online community rather than from traditional employees or suppliers.

[55]Dennis King, "The Haiti Earthquake: Breaking New Ground in the Humanitarian Information Landscape," *Humanitarian Exchange Magazine*, October 2010, 1, http://www. odihpn.org/humanitarian-exchange-magazine/issue-48/the-haiti-earthquake-breaking-new-ground-in-the-humanitarian-information-landscape (accessed July 30, 2013).

the European Union had provided major support and funding to CNIGS. Unfortunately, the earthquake destroyed the CNIGS building in Port-au-Prince, making its data resources unavailable in the immediate aftermath of the earthquake.[56] Aid workers on the ground such as Charlotte Lattimer, working with Save the Children in Haiti, felt the initial absence of baseline data for assessments. Lattimer tried to plan rapid needs assessments but needed the baseline GEOINT data that was destroyed during the earthquake.[57] While the disaster itself initially stifled use of GEOINT for assessment in Haiti, commercial vendors, LIDAR platforms, and the mobile-enabled population captured and shared the necessary data. First, the two largest US commercial satellite vendors, GeoEye® and DigitalGlobe®, provided vast amounts of pre- and post-earthquake high-resolution satellite imagery at no cost. Google also made available no-cost commercial imagery on known platforms such as Google Earth® and Google Maps®. Second, the US Air Force Global Hawk remotely piloted aircraft and the World Bank ImageCat® provided even higher resolution LIDAR imagery for the first time on public domains.[58] In the beginning of HA/DR operations, airborne assets collect LIDAR in damaged HA/DR areas, especially when High Resolution Terrain Elevation/Information (HRTE/I) is unavailable.[59] Third, the affected population became mobile-enabled. For the first time, members of the community affected by the earthquake issued pleas for help using social media and mobile technologies. Across the world, thousands of individuals mobilized on the Internet to aggregate and plot these

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[56]King, "The Haiti Earthquake: Breaking New Ground in the Humanitarian Information Landscape," 5.

[57]Crowly and Chang, *Disaster Relief 2.0: The Future of Information Sharing in Humanitarian Emergencies*, 17.

[58]ImageCat® collected LIDAR between 21 and 27 Jan 10.

[59]LIDAR is a remote sensing technology that measures properties of scattered light to find elevation data. This technology is useful in deriving one-meter gridded bare earth digital elevation model (DEM) (32-bit geographic tagged image file format), and three-dimensional (3-D) feature extraction for urban areas and vegetation (shape files).

pleas on maps to support the earthquake response.[60] Through the new ICT and three humanitarian communities of interest, Haiti set a precedent for a rich information environment in the immediate aftermath of a natural disaster that also facilitated baseline data for future comparisons. The challenge for a planner is learning how to tap into the rich information environment in a timely manner to gain insight for the key HA/DR decisions.

Leveraging GEOINT Support for Key Decisions

Knowing that there were several factors that delayed decisions in an already complex HA/DR environment, studying OUR also revealed that many planners recognized the need for GEOINT support to help sort out the mess. Today there are buzzwords that describe this phenomenon, Big Data[61]. Examining the OUR events highlighted four primary steps planners eventually took to leverage GEOINT support. First, to support timely decisions, planners had to translate the survivor needs, which mirrored the JTF-Haiti commander's priorities, into geospatial requirements. Knowing the requirements, planners identified the GEOINT datasets required to perform the analysis. If the datasets did not exist, assets gathered the data real-time. A good example of this happened on 25 January 2010, when GEOINT assets took forty-eight images over twenty-six targets in support of specific IDP movement.[62] Second, planners had to select the relevant data within those datasets to populate geodatabases for the Port-au-Prince area of interest (AOI). In between collection and analysis, management of GEOINT data was a vital step in the

[60]Crowly and Chang, *Disaster Relief 2.0: The Future of Information Sharing in Humanitarian Emergencies*, 66.

[61]Joshi, "Big Data: Putting Data to Productive Use," 40. "Data becomes Big Data, or rather a Big Data problem, when the volume, velocity, and/or variety of the data exceeds the abilities of your current IT systems to ingest, store, analyze, or otherwise process it."

[62]United States Southern Command, "JTF-HAITI Operation UNIFIED RESPONSE Briefing" (PowerPoint Presentation, United States Southern Command, Port-au-Prince, Haiti, January 25, 2010), 4.

process that supported timely decisions.[63] Not only do geodatabases minimize the amount of data on the workstation, they also speed up the geo-processing. Third, using the requirements and geodatabases, planners developed and processed GIS-based models tailored to each decision. Spatial analysis tools on a GIS provided the means to set the parameters within each requirement and to then apply map algebra to weight the model outputs. Fourth, the GIS model outputs easily produced a COP compatible with a variety of information management systems. The four-step process outlined above ultimately supported the key HA/DR decisions in Haiti. Examining the evolution of this process in more detail grants further insight to how planners can leverage GEOINT support in future HA/DR operations.

Prioritizing Survivor Needs for Key Decisions

In Port-au-Prince the most pressing needs were reestablishment of public order, food, medical care, and shelter. The seaports were damaged so most of the inbound aid had to come by air. Again, although the Haiti airport was undamaged, it quickly became jammed with logistical activity. Planners, therefore, focused on the decisions related to providing delivery sites, campsites, and locations for food distribution and for providing medical care. Each of the three decisions drove a different set of requirements defined by specific parameters for GIS analysis. First, campsites had a requirement to be away from the urban areas that were unsafe and unlivable following the earthquake.[64] Campsites also needed to be located on sloping terrain so that rainwater could drain away. Second, locations for food and medical care had to be close enough to dense displaced populations and away from damaged transportation nodes and routes. Third, LZs and DZs had to be sufficiently large, close to roads, and free of natural and manmade

[63]Verjee, *GIS Tutorial for Humanitarian Assistance*, 87. “A neglected aspect of humanitarian GIS is the proper management of spatial data.”

[64]Piper, “Post-Earthquake Recovery in Haiti: The Challenges Ahead,” 3.

obstacles. The LZs and DZs also had to be in flat areas for flight safety reasons. Meeting the parameters for all three requirements demanded selection of sites located away from flood-prone areas. These parameters defined the information requirements that drove the collection priority for LIDAR. In Haiti planners used LIDAR to conduct damage assessments and for flat open area searches:

> LIDAR "Bare Earth" model collection was exceptionally useful in identifying terrain characteristics around camps that indicated likelihood for flooding and mudslides, which greatly assisted Task Force engineer elements to conduct follow-up, on the ground surveys to verify GEOINT-derived assessments and identify high risk camps.[65]

Figure 2 shows a product planners produced on 22 January 2010 to find suitable areas for IDP camps. The product used LIDAR datasets.

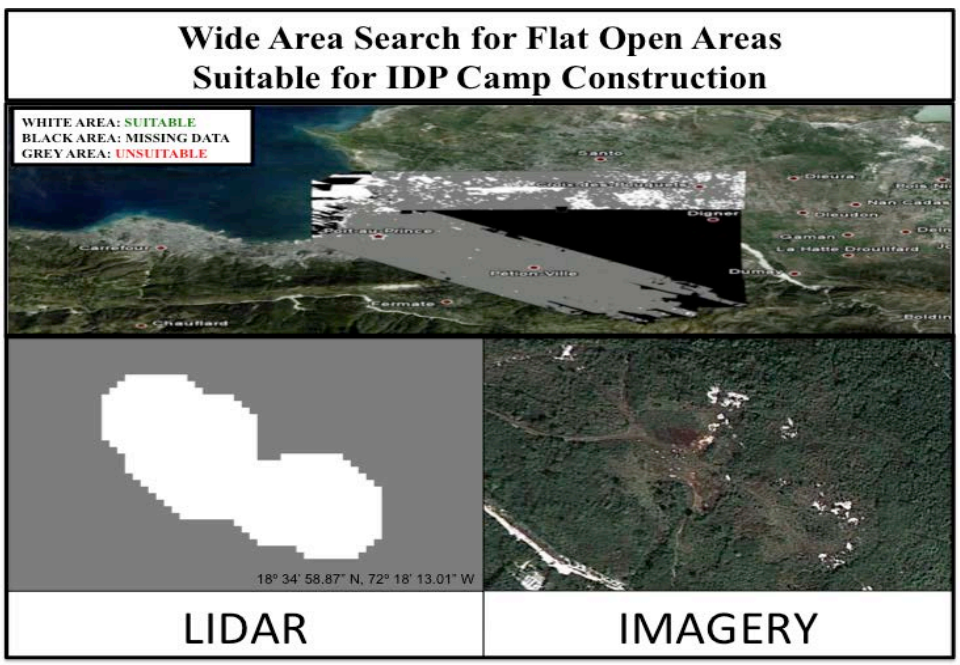

Figure 2. Haiti example of a wide area search for suitable IDP camps.[66]

Source: Data from United States Southern Command, "ALIRT LIDAR Analysis: Potential IDP Camp Areas 22 Jan 10" (PowerPoint Presentation, Port-au-Prince, Haiti, January 22, 2010).

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[65] *Operation Unified Response (OUR) Haiti Relief Mission SOUTHCOM AAR*, 6.

[66] Slope less than 10 degrees, low surface roughness, and width greater than 40 feet.

In this example, LIDAR reveals spatial relationships tied to terrain features not evident through imagery alone. The white area is suitable for IDP camps based upon the specific requirements and parameters. Using LIDAR to conduct wide area searches was a finding in the AAR. The report recommended, " . . . personnel should be educated on LIDAR data use in terrain analysis."[67] The OUR AAR highlights that support for timely decisions, such as the one to find open areas for IDP camps, requires GEOINT data and GIS analysis.

Populating Geodatabases from GEOINT Datasets

As the end-users of the technology that enables GIS analysis, planners must understand how to use GEOINT datasets at their workstations to feed models. At first, OUR planners did not understand the GEOINT data complexity. Prior to the earthquake and during the relief efforts, classified systems, commercial satellites, and airborne platforms collected geospatial data. This vast amount of pre-disaster geospatial data fed into several datasets tailored for Haiti. The datasets enhanced decision-making during the reconstruction and recovery phases of OUR.[68] As a guide for common datasets, JP 2-03 describes ten geodatabases continuously populated for standard products.[69] While these geodatabases provide a start, each HA/DR environment requires a specific geodatabase built around unique requirements. Even when requirements become apparent, the planner must understand two factors that affect geodatabase population: Cloud-based storage and geospatial metadata[70].

First, the move toward Cloud-based datasets has the potential to decrease the time to populate geodatabases. In 2010, the GIS community had started to move toward storing imagery

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[67]*Operation Unified Response (OUR) Haiti Relief Mission SOUTHCOM AAR*, 3.

[68]King, "The Haiti Earthquake: Breaking New Ground in the Humanitarian Information Landscape."

[69]JP 2-03 *Geospatial Intelligence Support to Joint Operations*, G-10–G-13.

[70]Metadata is data that describes a particular file embedded within that same file.

datasets on the Internet through Cloud-based storage, but the military community lagged behind the initiative.[71] Cloud-based storage requires connectivity and bandwidth to operate seamlessly. For example, the Environmental System Research Institute (ESRI), developer of ArcGIS, hosts Cloud-based imagery and related datasets. Through GeoRSS feeds, Web Mapping Services, and Web Features Services, planners can connect to Cloud-based GEOINT content and import the features they need into their own geodatabase. In addition, during OUR, the IC used mashups, or Internet websites that " . . . combined data, presentation, or functionality from two or more sources to create new services."[72] All of the Cloud-based examples listed above create more effective ways to share high fidelity GEOINT data on Internet sites. Combined with Cloud-based GIS, Cloud-based storage eliminates the need for client software. Planners can and should harness this open source, Cloud-based technology in future HA/DR operations to quickly build tailored geodatabases.

Second, geodatabase fidelity depends on geospatial metadata. Metadata provides labels and tags that allow planners to precisely track what data they import to the geodatabase. In Haiti, dataset accuracy was not a problem because the vast amount of the data was collected shortly before and immediately after the earthquake. In future HA/DR, however, data validation may be an issue if the disaster takes place in an area of the world where GEOINT data has not been collected. Planners must understand how GEOINT data is labeled and tagged in order to find the specific data they need for a geodatabase. In sum, planners must understand the path necessary to convert raw GEOINT datasets into useable geodatabases before GIS models can support key decisions.

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[71] "Appistry and Partners Showcase Cloud-Enabled 'Big Data' Solutions at GEOINT 2010 - Directions Magazine," Online Magazine, *Directions Magazine*, last modified November 3, 2010, http://www.directionsmag.com/pressreleases/appistry-and-partners-showcase-cloud-enabled-big-data-solutions-at-geoint-2/141220 (accessed July 23, 2013).

[72] Crowly and Chang, *Disaster Relief 2.0: The Future of Information Sharing in Humanitarian Emergencies*, 65.

Creating GIS-based Models to Support Key Decisions

During OUR, planners used the full range of GEOINT capabilities outlined in doctrine to predict and react to rapidly changing conditions. To perform the analysis necessary to support decision-making, planners used raw imagery, processed imagery intelligence, and geospatial information overlays. Each layer in a GIS model addresses a different requirement. For example, one requirement to find suitable helicopter LZs (HLZs) was slope. By setting the slope parameter in the model to less than ten degrees the model was able to identify a LZ site suitable for a CH-53 Sea King. The digital terrain elevation data found in the NGA DTED® dataset was used to calculate slope. Next, to ensure a buffer around the LZ free from all obstacles, a model parameter was set to fifty meters and the model used the LIDAR dataset to do the GIS analysis. Figure 3 shows one product generated in Haiti that shows suitable HLZs.

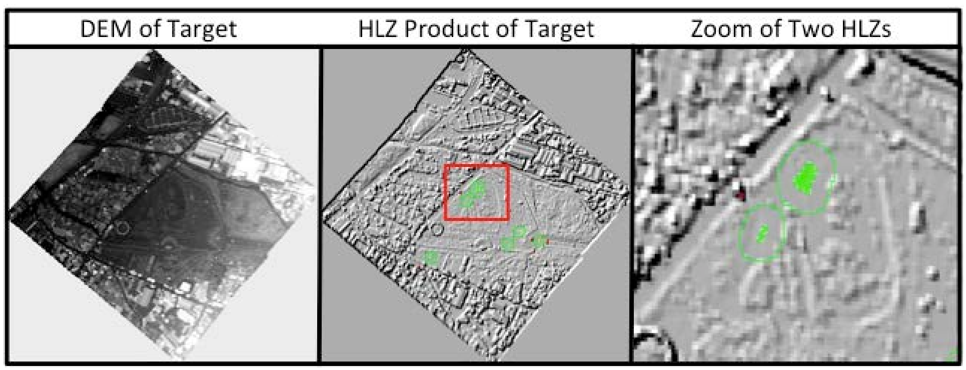

Figure 3. Two suitable CH-53 HLZs in Haiti generated from DTED® and LIDAR.

Source: Data from National-Geospatial Intelligence Agency, "NGA Haiti LIDAR HLZ Analysis" (PowerPoint Presentation, Port-au-Prince, Haiti, January 18, 2010).

In this example, the filled green area indicates acceptable CH-53 HLZs. The green outline indicates the fifty-meter buffer required. Each of the requirements became a separate layer in the model for suitable CH-53 HLZs. In a generic sense, what the Haiti planners produced was a GIS-based Assessment Model that predicted probable locations for HLZs based off specific inputs.

Figure 4 shows the primary components of a GIS-based Assessment Model, a tool used for prediction in all sorts of emergency response scenarios.[73]

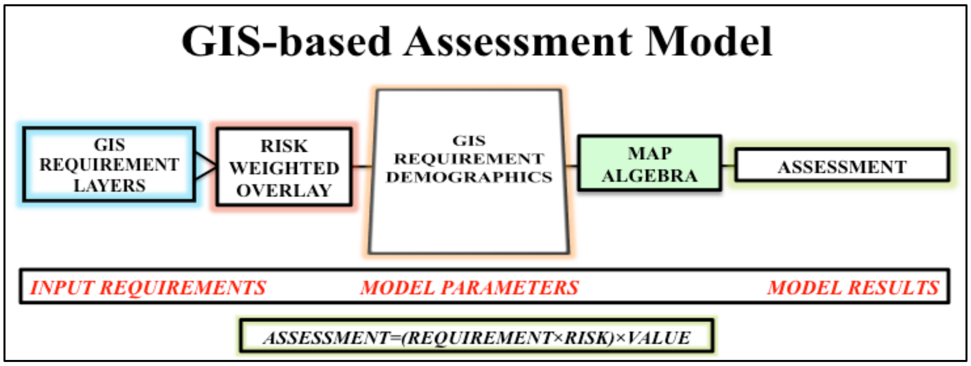

Figure 4. Major components of a GIS-based Assessment Model.

Source: Adapted from Russ Johnson, *Creating a Common Operational Picture with ArcGIS*, Online Training Seminar, 2013, http://training.esri.com/gateway/index.cfm?fa=catalog.webCourseDetail&courseID=1743 (accessed August 6, 2013).

To improve predictions the planner can apply risk to weight each layer in the model. Weighted risk gives the decision-maker a preference in shaping the assessment based off probabilities for success. Studying the GIS-based Assessment Model used by planners in Haiti facilitates a refined framework for solving problems in future HA/DR scenarios with GIS tools.

<u>A GIS Model Proposal</u>

As GIS and HA/DR continue to get more complex post-Haiti, the processes planners use to manage geospatial data must change if they are to keep up with advances in geospatial systems and the demands of HA/DR operations. Change is necessary because the complexity of the HA/DR information environment necessitates a framework that requires the use of GEOINT to make predictions. Such a framework must first help the planner to define the right problem. Defining the problem correctly ensures solving the problem is given priority. The problem

[73]Ona, "NGA-FEMA Cooperation Embraces New Practices, Emerging Technologies," 12.

definition also identifies the requirements and parameters needed to solve it, and limits the geographic AOI. At this point, a planner can determine whether sufficient GEOINT datasets and imagery are available to support a GIS-based model. Figure 5 summaries the author's six step method to solving HA/DR problems with GIS tools.

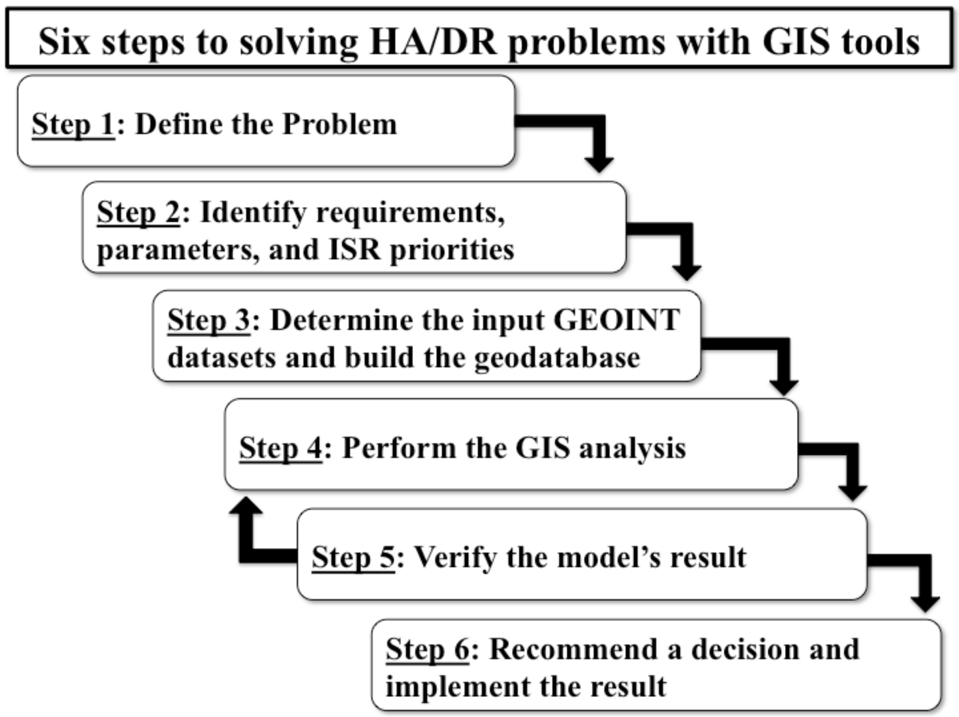

Figure 5. A six step conceptual GIS-based model that supports HA/DR decisions.

Source: Adapted from Firoz Verjee, *GIS Tutorial for Humanitarian Assistance* (Redlands, CA: ESRI Press, 2011), 273.

Armed with current GEOINT data, the planner must determine the requirements; e.g., close to roads and parameters; e.g., within fifty meters, that support a specific decision; e.g., where to place an IDP camp. Once the planner works through these information requirements, he can then populate a geodatabase and build a map algebraic model that provides predictions for the problem set. The planner must ensure that each GIS-model solves one specific HA/DR problem. This may require decomposition, or breaking a larger problem down into parts.[74] After the model has been run, the planner must verify the results and adjust the model as necessary. This step describes how the process is iterative and can adapt to changing conditions in the environment. Once the results provide viable options for a desired location and time, the planner can recommend a decision to the commander and the decision can be depicted in a GIS-based COP.

Designing GIS-based COPs for Enhanced Coordination

To enhance coordination amongst a variety of users the planner must design the GIS-based COP to show only pertinent decision-making information. The SOUTHCOM AAR for JTF-Haiti identified the COP as knowledge management at its best and worst.[75] In Haiti, responders clearly lacked situational awareness in the beginning. The creation of a command and control structure that effectively integrated non-military personnel improved situational awareness. The crucial element that increased situational awareness for all agencies in Haiti was the creation of a GIS-based COP.[76] Figure 13 in appendix A shows is the 27 January 2010 daily COP distributed in Adobe GeoPDF® format. The GIS-based COP had thirty-one GIS layers, including unit locations, displaced survivor locations, and the estimated risk of floods and landslides.[77] Planners shared the COP in several GIS output formats on Intelink's Intellipedia®,

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[74]James G. March, *A Primer on Decision Making: How Decisions Happen* (New York, NY: Free Press, 1994), 12.

[75]LTG P.K. Keen et al., "Foreign Disaster Response: Joint Task Force-Haiti: Observations," *Military Review* 90, no. 6 (November 2010): 85–96, http://www.docstoc.com/docs/68883695/FOREIGN-DISASTER-RESPONSE-Joint-Task-Force-Haiti-Observations (accessed July 11, 2013); Keen, "Joint Task Force-Haiti Observations and Recommendations," 3.

[76]Mitchell T. Koch, *HA/DR Lessons Learned*, After Action Report (Newport, RI: Naval War College, May 4, 2011), 10, http://www.dtic.mil/docs/citations/ADA546338 (accessed October 13, 2013).

[77]National-Geospatial Intelligence Agency, "Haiti Distribution Points, Internally Displaced Persons, Flood and Landslide Risks" (Adobe GeoPDF, National-Geospatial Intelligence Agency (JTF-H), Port-au-Prince, Haiti, January 27, 2010).

Defense Connect Online, Military Internet Relay Chat, and the APAN.[78] Communications through the COP had a profound impact on building situational awareness, particularly in the beginning stages of the HA/DR. In the future, HA/DR operation planners must not forget the role the GIS-based COP has in supporting key logistical decisions.

VALIDATION OF GEOINT-BASED HA/DR DECISIONS IN SOUTH SUDAN

In the Haiti case planners initially struggled to make timely decisions and subsequently used GEOINT to improve decision-making and speed assistance. The case study alone does not prove that GEOINT support in HA/DR operations is essential. Generalizing Haiti case study's observations required analysis of a similar but related case using existing datasets and GIS tools. One way to validate the utility of GIS tools was through assessment of a likely HA/DR scenario in a different geographic location. The data derived from a new location permitted a comparison between the need for GEOINT support in Haiti and requirements in a similar disaster albeit in a different location.

Juba, South Sudan, was chosen as the scene of a great earthquake with an epicenter along the border between South Sudan and Uganda. Juba worked well for four reasons. First, Juba revealed the impact of rapid urban growth on GEOINT. "Since 2005 Juba [has] recorded spectacular urban expansion, at upwards of 12.5% per year, among the fastest rates urbanization rates in human history."[79] Between 2005 and 2012 Juba's population more than doubled to six hundred thousand people.[80] Second, Juba has relatively poor infrastructure, even when compared to cities in Sudan such as Khartoum. Poor infrastructure equates to an even more complex

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[78]King, "The Haiti Earthquake: Breaking New Ground in the Humanitarian Information Landscape," 2.

[79]Grant and Thompson, "The Development Complex, Rural Economy and Urban-Spatial and Economic Development in Juba, South Sudan," 1.

[80]Ibid. Six hundred thousand is an estimate since the last census was 2008.

HA/DR environment following an earthquake. Third, the African Tectonic Plate meets the Arabian Tectonic Plate 160 kilometers south of the city making the city vulnerable to earthquakes in the midst of existing chaos. Even without the potential of seismic activity leading to an earthquake, Juba faces a plethora of natural and man-made problems. These include ethnic war, humanitarian crisis occasioned by water shortages and endemic disease, and armed atrocities against civilians.[81] Lastly, the development of existing datasets for Juba lags behind those of other cities in Africa. The South Sudan study showed that Khartoum has a relatively larger GEOINT database than Juba. Because of the rapid urbanization, much of the GEOINT data that does exist for Juba is obsolete. Outdated GEOINT data is a practical lesson. A planner will often not have the best GEOINT data available in the immediate aftermath of a disaster and, therefore, needs to know how prioritize ISR collection based upon decisional requirements. For the reasons above Juba was an ideal location to validate GEOINT's role in supporting key HA/DR decisions.

Juba's GEOINT Data

The experiment began, as would any HA/DR planning endeavor using GEOINT and GIS tools, by collecting data from several open sources. Table 2 shows some typical sources of spatial data used by the author in the Juba experiment and available to future HA/DR planners.

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[81]Stephanie Beswick, *Sudan's Blood Memory: The Legacy of War, Ethnicity, and Slavery in Early South Sudan*, Rochester Studies in African History and the Diaspora v. 17 (Rochester, NY: University of Rochester Press, 2004), 5.

Table 2. Compiled list of HA/DR spatial data resources encountered.

RESOURCE	DESCRIPTION OF SPATIAL DATA
Commericial Data/Maps	Basemaps; thematic ArcMap documents; streetmaps; raster, vector, elevation, and census data
National Geospatial-Intelligence Agency (NGA)	Geospatial Data Navigator (GDN); Web-based Access and Retrieval Portal (WARP); GEOINT Base for Contingency Operations (GIBCO)
Defense Logistics Agency (DLA)	Hard copy imagery and where to order GIBCO
US Army Geospatial Center (AGC)	Geospatial Readiness Center (GRC), Theater Geospatial Database (TGD), BuckEye, Common Map Background (CMB), DAGR Map Support, Engineering Route Study (ERS), AGE GeoGlobe, GEOPDFs, LIDAR, Urban Tactical Planner (UTP)
Geographic Data Portals	ArcGIS (ESRI) Online, GeoRSS feeds, Mashups, Web Mapping Service (WMS), Web Feature Service (WFS), OpenStreetMap, UN Geographic Information Working Group (UN GIWG), Famine Early Warning Systems Network (FEWS NET)
Global Spatial Data Infrastructure (GSDI)	National or regional spatial data infrastructure
Local Organizations	Data-sharing relationships with local governments and institutions
Field Collected/Generated	GPS receivers, smart devices, air and ground reconniassance, unmanned aerial systems (UAS), imagery intelligence (IMINT) or human intelligence (HUMINT)
Data Association	Existing databases joined with point or polygon spatial data layers [i.e. UN Office for the Coordination of Humanitarian Affairs (UN OCHA)]
HYPERLINKS	
(CAC Only) GDN:	**https://gdn.geointel.nga.mil/gdn/gdn.cgi (also available on SIPRNET/JWICS)**
NGA | (CAC Only) GEOINT ONLINE:	**http://ww.nga.mil | https://geoint-online.nga.mil**
(CAC Only) WARP:	**https://warp.nga.mil (also available on SIPRNET/JWICS)**
AGC | (CAC Only) AGC PROGRAMS	**http://www.agc.army.mil | https://cac.agc.army.mil/Products**
ESRI | ArcGIS ONLINE:	**http://www.esri.com | http://www.arcgis.com**
FEWS NET:	**http://earlywarning.usgs.gov/adds**
GIBCO:	**http://www.intelink.gov/wiki/GIBCO (also available on SIPRNET/JWICS)**
GSDI:	**http://gsdi.org/SDILinks.asp**
UN GIWG:	**http://www.ungiwg.org/data.htm**
UN OCHA:	**http://ochaonline.un.org/Geographic/tabid/1084/Default.aspx**

The data used for the Juba scenario came primarily from commercial vendors and the NGA. The author pulled spatial data in three forms: map data, attribute data, and image data.[82] Map data provided the pictorial backdrop for comparison while the attribute and image data provided the information and terrain layers for the GIS models. Between commercial vendors and the NGA, four general categories for GEOINT datasets populated the author's Juba geodatabase. First, upon formal request, the NGA provided one hundred gigabytes of GIBCO data to enable realistic analysis and processing.[83] This process paralleled the real-world process. Appendix C depicts the contents of the "Sudan Country" GIBCO datasets. Note that the GIBCO contents account for all datasets in the coverage area but do not specifically list datasets for Juba. For example, coverage for Khartoum was much better because it included higher fidelity imagery and terrain data along with more GIS workspaces. The GIS workspaces from GIBCO provide more of natural and urban terrain analysis, an attempt to reduce the spin up time for HA/DR planners.

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[82]Verjee, *GIS Tutorial for Humanitarian Assistance*, 2.

[83]The NGA delivered the data via Federal Express overnight mail on 24 DVDs.

Second, the UN Office for the Coordination of Humanitarian Affairs (OCHA) made several HA/DR datasets available that the author used in the Juba geodatabase. These datasets aligned with Common Operational Datasets (CODs), or priority data groupings for HA/DR GEOINT data.[84] The datasets for South Sudan were downloaded from the UN OCHA website.[85] Appendix B outlines the CODs that comprise the Inter-Agency Standing Committee (IASC) guidelines for disaster preparedness and response. The IC focuses HA/DR data organization around these IASC guidelines. The South Sudan study revealed an overwhelming number of Internet datasets for Africa, but the best open source spatial data for the Juba scenario came from the UN OCHA website.

Third, to examine the impact of older map data on decision-making the author intentionally used Web-Access Retrieval Portal (WARP) imagery to populate the Juba geodatabase.[86] The most current WARP imagery for Juba was one-meter multispectral imagery taken from the GeoEye® IKONOS™ satellite in 2005. The WARP imagery was still more current than the Controlled Image Base (CIB®) one-meter imagery from the GIBCO datasets. Note that the IKONOS™ multispectral composition also granted clarity to the analysis. While both sources of imagery come from commercial vendors, CIB® is orthorectified[87] using the NGA's Digital Terrain Elevation Data (DTED®). Orthorectification makes the geographic

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[84]CODs include: administrative boundaries, populated places, transportation networks, hydrology, and hypsography. All of these GEOINT datasets are important to support decision-making with GIS tools.

[85]"Humanitarian Response COD-FOD Registry," *UN OCHA*, last modified August 14, 2013, http://cod.humanitarianresponse.info/search/field_country_region/176 (accessed August 15, 2013).

[86]In December 2013 the NGA announced WARP retirement by June 2014. Advancements in capabilities and the future implementation of the NSG Consolidated Library (NCL) will provide greater, more effective dissemination of NGA products to the NGA customers.

[87]"Raster Product Format," Government, *Sustainability of Digital Formats Planning for Library of Congress Collections*, last modified October 27, 2011, http://www.digitalpreservation.gov/formats/fdd/fdd000298.shtml (accessed November 11, 2013). The topographical variations in the surface of the earth and the tilt of the satellite or aerial sensor affect the distance of displayed features. The more topographically diverse the landscape is, the more inherent photographic distortion.

coordinate information linked to the elevation data more precise. Thus, in light of the rapid urban growth in Juba, the author chose the 2005 IKONOS™ WARP imagery over newer commercial and orthorectified imagery. The deliberate use of older imagery highlighted a lesson for future planners also identified in the Haiti case study. It re-emphasized the need for assets to collect GEOINT imagery before and after a disaster. Because fidelity degrades with time, especially in a rapidly changing HA/DR environment, GEOINT can actually mislead HA/DR decisions if imagery is not current.

Fourth, populating the Juba geodatabase highlighted another lesson that emerged from the GIBCO elevation data available for Juba. The elevation data available was the lowest quality SRTM dataset:

> Elevation data have varying levels of detail: DTED® Level 1 (roughly 90-meter post spacing, bare earth), DTED® Level 2 (30-meter post spacing, bare earth), shuttle radar topography mission 2 (30-meter post spacing, reflective surface or "treetop" data), and high-resolution elevation data. DTED® is intended for lower-resolution viewing of large areas and is not appropriate for tactical planning that requires higher-resolution viewing. DTED® Level 1 provides approximately the same level of detail that the contour lines of a 1:250,000-scale map joint operational graphic does.[88]

The provided GIBCO coverage included only DTED® Level 1 for South Sudan. Figure 16 in appendix E shows the gain in fidelity from closer post spacing, thanks to continued SRTM collection across the world. As the SRTM continues, the higher quality elevation data, with closer post spacing, will become available for the entire world. The closer the post spacing, the more a planner can zoom in and make accurate slope measurements. While sufficient to perform elevation and slope analysis for Juba, ninety-meter post spacing in areas of rugged terrain requires more data points. Fortunately, Juba is not rugged or mountainous, so the DTED® Level 1 datasets used by spatial analysis tools to process slope and elevation requirements produced sufficient results.

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[88]ATTP 3-34.80 *Geospatial Engineering*, 1-3.

After collecting sufficient GEOINT datasets, the next step focused on only the data needed for the GIS analysis. To filter and clip the datasets and imagery, the author built an AOI around Juba to establish the earthquake-affected areas. Framing the boundaries before populating the geodatabase reduced the size of the database.[89] The AOI was 156 square kilometers (13 by 12 kilometers) roughly the dimensions of the Kansas cities of Leavenworth and Lansing combined. Within minutes, basic GIS tools produced the elevation (433 to 1199 meters) and slope ranges (0 to 46.38 degrees) and identified key terrain features (e.g., White Nile River flowing at 447 meters elevation) within the Juba AOI. Even at this early validation stage, processing GEOINT data with a GIS revealed information that cannot be easily extracted from other resources such as paper maps. Furthermore, to minimize the size of future COP outputs and to speed up geo-processing, the author clipped each feature dataset imported to the Juba geodatabase to within the Juba AOI. Think of GIS clipping as similar to cropping a photo to get rid of excess information on the outsides of the subject area. At the end of data import, the Juba database was five hundred megabytes rather than the one hundred gigabytes of data initially collected. At the end of the modeling, the GIS-layered map document was only five megabytes. In summary, an AOI around Juba filtered the available datasets, set up the geodatabase for future COP sharing, and focused the author on HA/DR requirements for the GIS model.

Juba's GIS-based Model

Armed with adequate GEOINT data focused within Juba's AOI, the next step was to develop a problem-solving model with routine GIS tools. This project used ArcGIS Desktop 10.2, specifically ArcMap® to model the disaster situation. ArcMap® offers three primary GIS

[89]The author projected the IKONOS™ one-meter imagery onto Universal Transverse Mercator (UTM) zone 36N, datum WGS84. This projection was necessary to meet military standards for planning, to seamlessly fuse with existing datasets, and to permit metric units in the measurements and model results.

extensions applicable to HA/DR: Spatial Analyst, Network Analyst, and Geostatistical Analyst.[90] Table 3 shows the GIS extensions and tools the author used in the Juba scenario, derived from the user friendly “find a tool” feature of ArcGIS 10.2.

Table 3. Summary of ArcGIS 10.2 tools used for basic spatial analysis.

ArcGIS 10.2 Desktop Extension	ArcMap Tool	Summary
Conversion	Layer to KML	This tool converts a feature or raster layer into a KML file containing a translation of Esri geometries and symbology. This file is compressed using ZIP compression, has a .kmz extension, and can be read by any KML client including ArcGIS Explorer, ArcGlobe, and Google Earth.
	Map to KML	This tool converts a map document into a KML file containing a translation of Esri geometries and symbology. This file is compressed using ZIP compression, will have a .kmz extension, and can be read by any KML client including ArcGIS Explorer, ArcGlobe, and Google Earth.
	Polygon to Raster	Converts polygon features to a raster dataset.
	Raster to Polygon	Converts a raster dataset to polygon features.
Coverage	Dissolve	Creates a new coverage by merging adjacent polygons, lines, or regions that have the same value for a specified item.
Data Management	Project	Projects spatial data from one coordinate system to another.
Spatial Analysis	Buffer	Creates buffer polygons around input features to a specified distance.
	Clip	Extracts input features that overlay the clip features.
	Erase	Creates a feature class by overlaying the Input Features with the polygons of the Erase Features. Only those portions of the input features falling outside the erase features outside boundaries are copied to the output feature class.
	Raster Calculator	Builds and executes a single **Map Algebra** expression using Python syntax in a calculator-like interface.
	Reclassify	Reclassifies (or changes) the values in a raster.
	Slope	Identifies the slope (gradient, or rate of maximum change in z-value) from each cell of a raster surface.

Source: Data from Environment Systems Research Institute, “Desktop Help 10.0 - Welcome to the ArcGIS Help Library,” *ESRI*, last modified July 30, 2013, http://help.arcgis.com/en/arcgisdesktop/10.0/ help/ (accessed July 30, 2013).

The GIS Spatial Analyst extension provides the principal means to explore spatial relationships between datasets. It is the most basic but nevertheless useful method for spatial analysis using ArcGIS 10.2. Spatial Analyst tools such as the Raster Calculator solved models that enhanced decisions in the Juba scenario. The Network Analyst extension extends spatial relationships to networks for further analysis. A search for optimized directions using navigation software like Google Maps® uses this form of analysis. Network Analyst requires network datasets, or geometric networks that are expensive to obtain or difficult to build. Network datasets take much more time to collect, find, organize, and share the data. The time-intensive process is what makes

[90]ArcGIS is a line of GIS software products. The four primary frameworks are ArcGIS Desktop, ArcGIS Mobile, ArcGIS Server, and ESRI Data. ArcGIS Desktop is the primary application used to compile, author and use geographic information and knowledge. The three functional levels are ArcView®, ArcEditor™ and ArcInfo™. ArcMap®, ArcCatalog®, and ArcToolbox® are the applications that exist in all functional levels of ArcGIS Desktop.

network datasets relatively expensive.[91] Last, the Geostatistical Analyst provides a variety of tools for " . . . spatial data exploration, identification of data anomalies, optimum prediction, evaluation of prediction uncertainty, and surface creation."[92] The author did not need the Geostatistical Analyst since the Spatial Analyst extension met the analytical requirements to build models supporting the three key HA/DR decisions. Expert GIS analysts routinely use all three of these extensions to model disaster relief problems. Therefore, making use of all three extensions to perform HA/DR problem solving in complex decisions may require planners to communicate requirements to expert GIS analysts.

Planners must also understand the difference between raster and vector GEOINT data prior to GIS modeling or effectively communicating requirements to GIS experts. There are two kinds of GIS data models: raster and vector. A typical raster data model represents geographical information as a collection of layers or themes, composed of cells in some particular order. On the other hand, a typical vector data model describes geographical features as points, lines, or polygons by coordinates.[93] Understanding the coding of these two models guides the tools to choose within the GIS workspace and at each phase of the spatial analysis. Once a planner has a basic understanding of GEOINT data formats and ArcGIS, the planner can then build a GIS-based model tailored to support a HA/DR decision.

Following steps one through three of the six step conceptual model introduced in figure 5, the author broke the HA/DR decisional requirements into three distinct, simpler GIS problems. Each GIS problem used different tools from the Spatial Analyst extension. Separate GIS problems also made logical sense since each key HA/DR decision addresses a different, yet

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[91]Smith and Overton, "Sharpening Your GIS Skills."

[92]Environment Systems Research Institute, "ArcGIS Geostatistical Analyst--Overview," *ESRI*, last modified June 15, 2013, http://www.esri.com/software/arcgis/extensions/geostatistical (accessed November 11, 2013).

[93]Feng-Tyan, "Many Sorted Algebraic Data Models for GIS," 770.

potentially connected aspect of the holistic HA/DR system. At this point there was a desire to optimize since there are shared physical relationships between the requirements behind each decision. However, achieving optimization in the modeling immediately conflicted with building the models quickly. Building separate GIS models free of optimization will translate to more timely decisions in logistics-heavy, HA/DR operations. The tradeoff for the faster speed is a lack of efficiency. For instance, selecting campsites close to food DPs may optimize efficiency in the holistic system, but may not be practical based off the requirements, parameters, and time necessary to make each separate decision. To mitigate adding further complexity that impedes timely decision-making, only after a planner addresses each individual decision should optimization take place using the Network and Geostatistical Analyst extensions.

Applying the simpler GIS approach free of efficiency, the GIS-based solution recommending a single HA/DR decision answered the generic question: "How does GEOINT data and GIS tools guide a key HA/DR decision?" Figure 6 conceptually portrays the relationships between the major parts of a Spatial Analyst extension-based analytical model that supports individual HA/DR decisions.

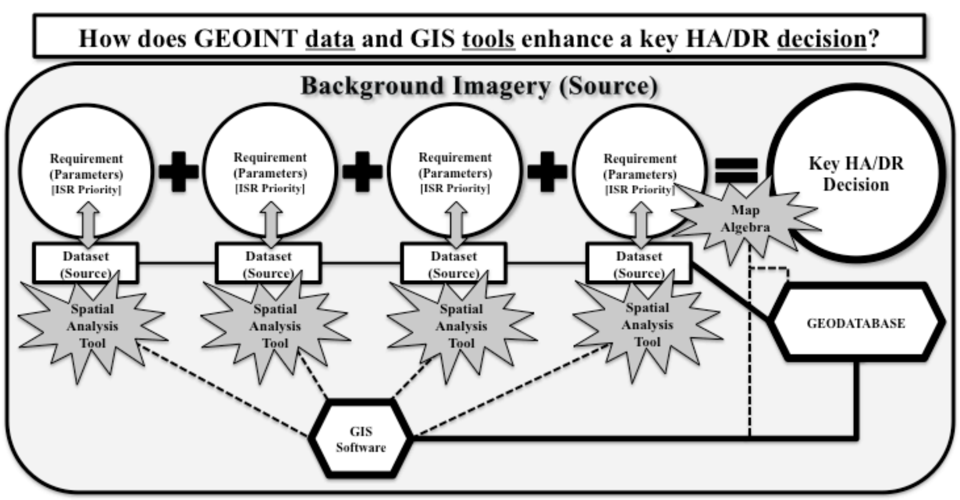

Figure 6. A GIS-based model concept using ArcGIS Spatial Analysis extension tools.

This approach focuses the planner on the requirements, parameters, datasets, and GIS tools needed to enhance one key decision in the timeframe necessary to save lives. Breaking the HA/DR decisional requirements into three distinct spatial problems also enabled a more detailed analysis for each key decision.

The three distinct spatial problems facilitated two main activities essential for modeling key HA/DR decisions: establishing ISR collection priorities for new GEOINT datasets and solving GIS-based models with map algebra. First, individual requirements aided in early prioritization of ISR collection assets. In the Juba scenario, high priorities for collection included higher fidelity elevation data and newer imagery. Better elevation data through HRTE/I enabled more accurate slope parameters that propagated through the model, resulting in higher fidelity, and thus more accurate, decisions. Change detection is an important requirement of a GIS model for HA/DR that LIDAR best enables. As identified in the Haiti study, there is no better way than LIDAR to remotely assess changing urban environments, vegetation, and ground composition today.[94] Likewise, current imagery updates damage assessments while it helps planners identify build up areas, changing terrain features, and obstacles to logistics movement. Second, breaking the larger problem into manageable parts led to a solvable map algebraic expression based off unique parameters.[95] In ArcGIS 10.2 the Raster Calculator tool performs map algebra on the GIS layers and variables. For example, figure 7 shows the actual map algebraic expression used by the author to find for suitable campsite locations in Juba.

[94]Clayton Crawford and Raghav Vemula, "5 Ways to Use Lidar More Efficiently," *ArcUser* (Summer 2013), http://www.esri.com/esri-news/arcuser/summer-2013/5-ways-to-use-lidar-more-efficiently?goback=.gde_1770697_member_257674320 (accessed July 23, 2013).

[95]Feng-Tyan, "Many Sorted Algebraic Data Models for GIS," 767.

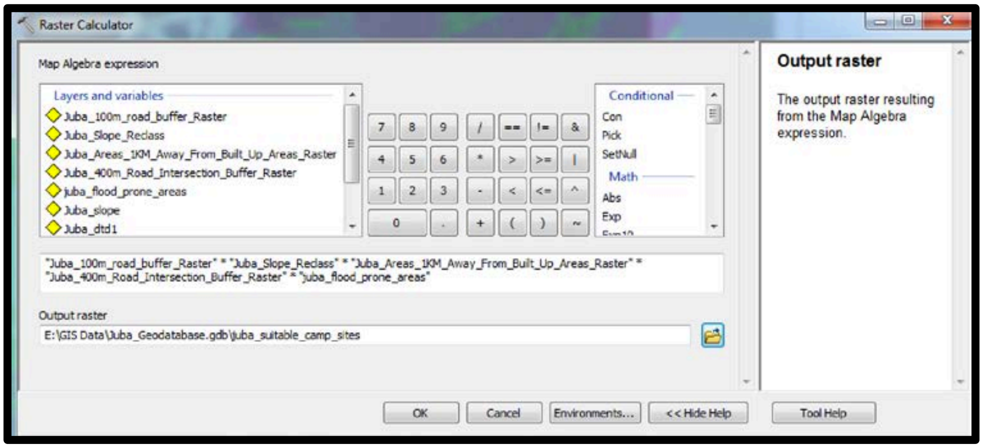

Figure 7. Map algebraic expression in the Raster Calculator tool to find Juba campsites. *Source:* Screenshot showing the ArcMap® (ArcGIS 10.2) Raster Calculator tool window.

Since each feature dataset possessed these parameters, or attributes in GIS terminology, the author classified the measured data into weighted values using map algebra. Current datasets and map algebra, the two main ingredients for GIS-based decision support models, must be understood and managed by the planner from the beginning.

Understanding the GIS-based decision support model helps the planner identify and prioritize the model variables for each key HA/DR decision. The first key decision validated in the Juba scenario supported by GEOINT and GIS tools was the selection of suitable campsites. The author identified five main requirements to be true for a campsite to be suitable. Figure 8 shows the requirements, parameters, datasets, imagery, and spatial analysis tools used to find suitable campsites in the Juba AOI.

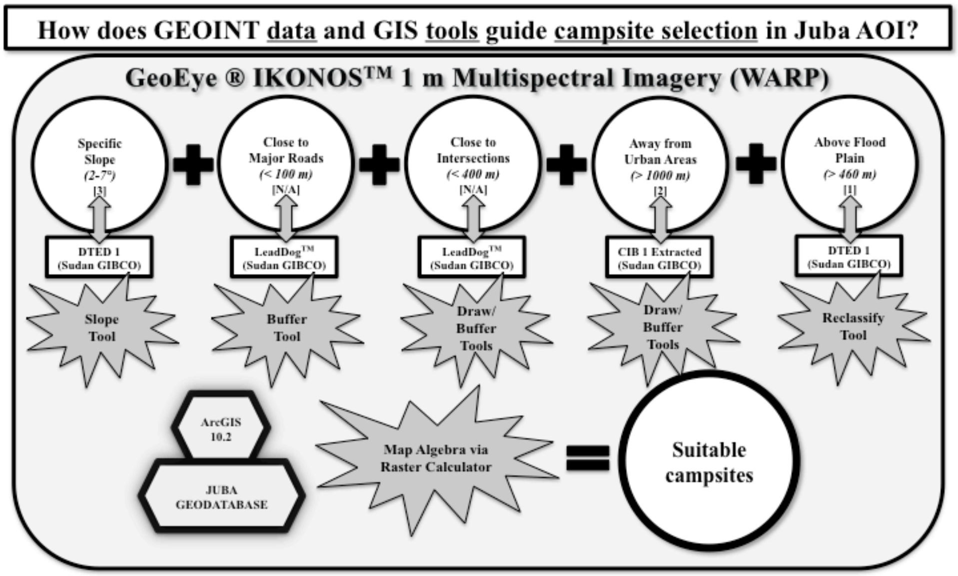

Figure 8. Analytical objectives of the GIS-based model for campsite selection.

First, a slope parameter between two and seven degrees ensures good drainage within the campsite. If the gradient is too flat, the area becomes prone to flooding in rainy seasons. In addition, " . . . standing water acts as a breeding ground for vector-borne diseases such as malaria" and a variety of other health risks.[96] Second and third, being close to roads and road intersections are important to facilitate movement to and from the campsite for survivors, in addition to logistics resupply of food and medical aid from aid agencies. Fourth, being away from urban areas provides safety and security to survivors. Haiti showed how the second and third order effects from earthquake damage in urban areas threaten the lives of survivors. Moving campsites away from infrastructure and crime-prone areas protects survivors. Fifth, suitable locations must be outside of flood zones. In this model, the author chose all elevations greater than 460 meters, or 13 meters above the White Nile elevation, as low risk areas for flooding.

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[96]Verjee, *GIS Tutorial for Humanitarian Assistance*, 272.

The second key decision validated in the Juba scenario supported by GEOINT and GIS tools was the selection of food DPs. The author identified four main requirements to be true to identify possible food DPs. Figure 9 shows the requirements, parameters, datasets, imagery, and spatial analysis tools used to find food DPs in the Juba AOI.

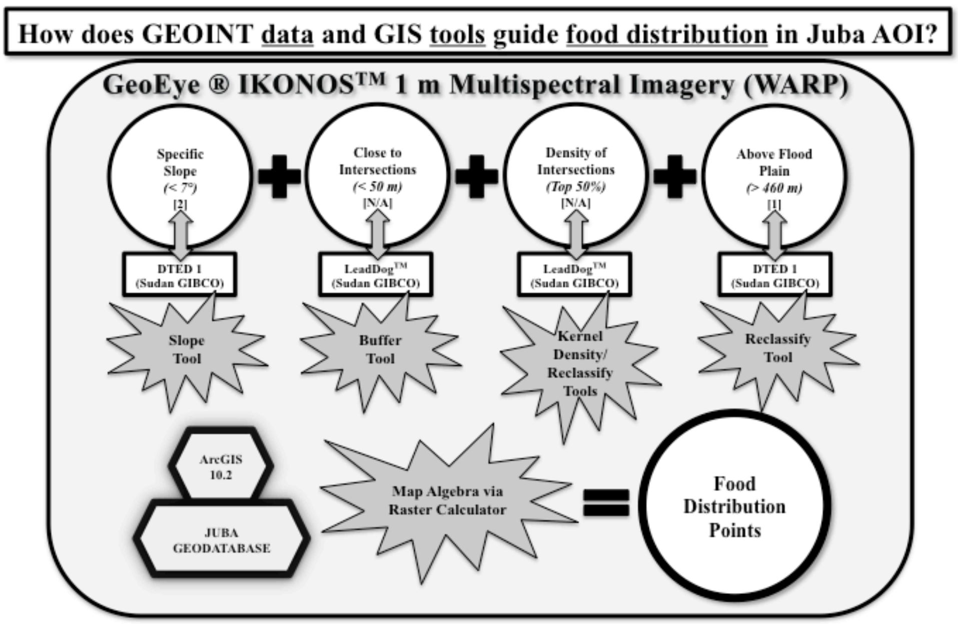

Figure 9. Analytical objectives of the GIS-based model for food distribution.

First, slope was not as important of a requirement for this decision so completely flat areas were included, along with minor slopes less than seven degrees. Second, being less than fifty meters from intersections was important, since food DPs need to be located in close proximity to survivors in urban areas. An assumption was that intersections correspond to where people live in urban environments. Since the population density for Juba was unavailable, the author used this assumption to generate intersection buffers from the LeadDog™ road dataset. Third, to add another layer for better decision-making, another requirement was for the food DP to fall in areas bounded by the top fifty percent of all intersection densities. The assumption here is that the intersection densities correspond to the living area densities, where survivors likely remain. Fourth, the requirement remained for food DPs to remain away from flood-prone areas.

The third key decision validated in the Juba scenario supported by GEOINT and GIS tools was the selection of suitable LZs and DZs. The author identified five main requirements to be true of LZs and DZs suitable for a CH-47 helicopter, and a C-17A aircraft, respectively. The only requirement that differed between rotary and fixed-wing aircraft was the minimum open area dimensions. Figure 10 shows the requirements, parameters, datasets, imagery, and spatial analysis tools used to find suitable LZs and DZs in the Juba AOI.

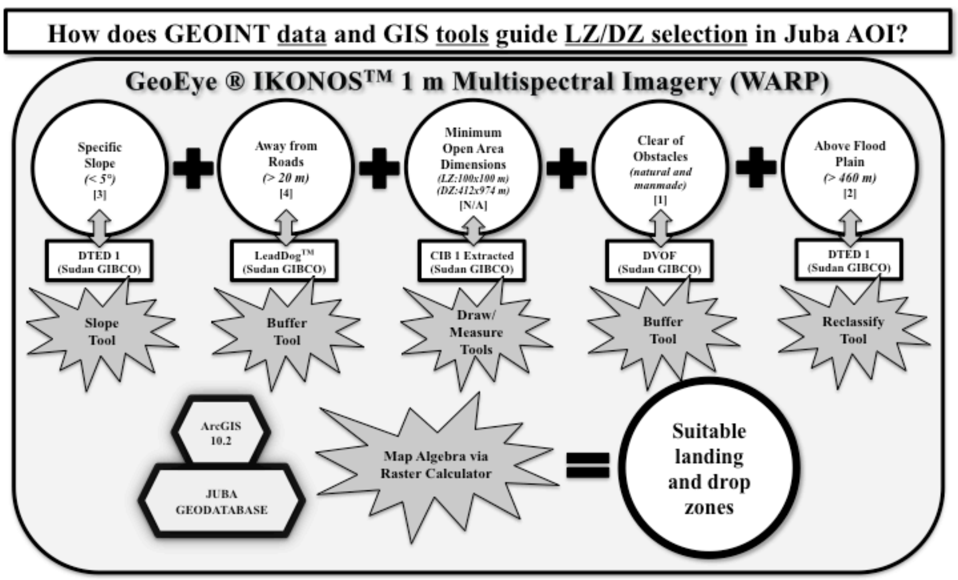

Figure 10. Analytical objectives of the GIS-based model for LZ/DZ selection.

First, a slope less than five degrees is a conservative requirement for safe helicopter operations. Second, being close to roads is important, but there should be a twenty-meter safety zone for aircraft performing airdrop and air landing delivery of supplies. Third, the author chose one hundred by one hundred meter minimum dimensions for a CH-47, equivalent to ten thousand square meters for polygon-shaped LZs. For a C-17A performing container delivery system (CDS) bundle airdrop with low velocity parachutes, US Air Force regulations and experiences dropping water and Class I from the Haiti AARs influenced the DZ size. To meet this requirement the minimum DZ is 412 meters in width by 974 meters in length.[97] This ground area allows a single C-17A at a drop altitude up to six hundred feet above the ground to deliver a full load of forty CDS bundles.[98] Fourth, the LZ and DZ solutions must target open areas for safety of ground personnel and preservation of delivered resources. Minor vegetation and trees can remain on the LZ or DZ, provided they do not impede safe operations. In all cases man made obstacles such as cell phone towers and buildings must remain outside the lateral confines of the LZ or DZ. The author had to verify the model results to fulfill these requirements because data was not available for horizontal and vertical obstructions in Juba. Fifth, the requirement for suitable LZs and DZs to stay away from flood-prone areas remained.

Juba's GIS-based Model Results

The GIS analysis within Juba produced useful products for decision-makers in pictorial and numerical formats. To generate visual products, the author had to convert the model's digital outputs from ArcGIS into compatible graphic formats. Three steps enabled the conversion. First, creating a raster layer dataset for each model result made visible products possible. Second, each dataset classified locations for each HA/DR decision that required verification by the author. Third, since each model produced suitable areas, the author could quickly evaluate against the IKONOS™ one-meter imagery to choose five suitable campsites, twelve food DPs, sixteen LZs, and six DZs. Figure 11 depicts the layout view of the ArcMap® Juba data frame with separate layers for the suitable and selected locations.

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[97]The minimum DZ for a C-17A using high velocity parachutes is 531 meters wide by 1472 meters long up to a drop altitude of 3,000 feet above the ground.

[98]AFI 13-217 *Drop Zone and Landing Zone Operations*, 9.

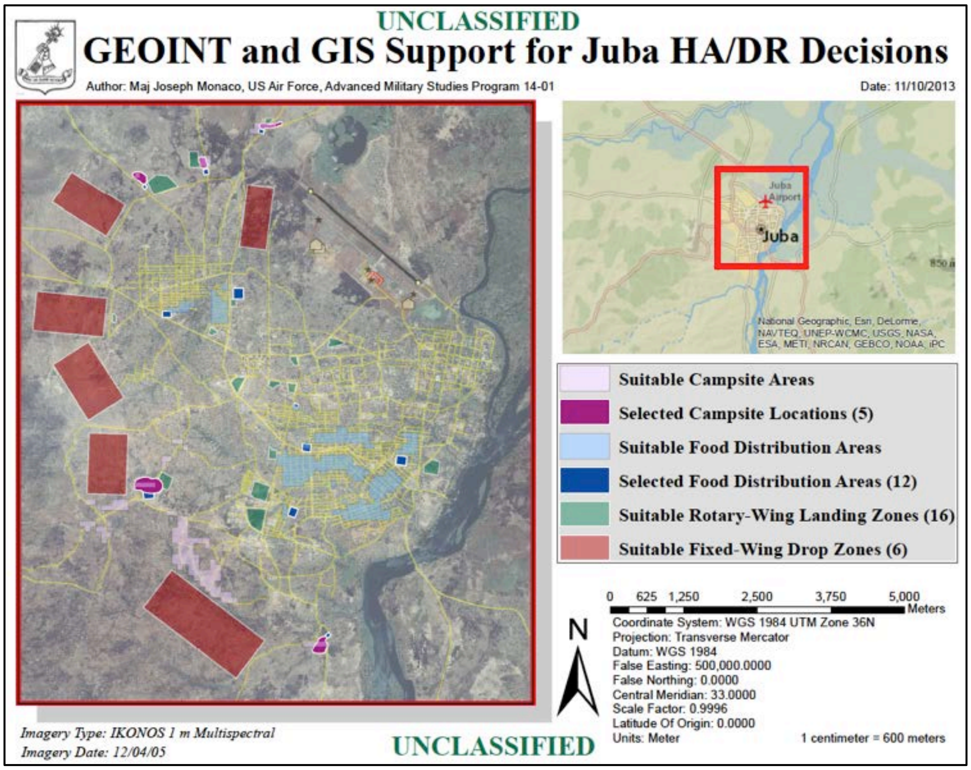

Figure 11. Product depiction of the author's GIS-based model results for Juba.

The author created this pictorial formatted product using the "Export Map to Adobe PDF" feature of ArcGIS Desktop 10.2. Across all HA/DR stakeholders, there will likely be a limited number of planners using ArcGIS. Fortunately, ArcGIS also has GIS tools to seamlessly output the model results to other GIS formats. For example, the author used the "Map to KML" conversion tool to quickly generate a Google Earth® KMZ file to share the Juba COP to a wider spectrum of users. Figure 14 in appendix D shows a Google Earth® snapshot depiction of the results from the Juba validation.

In addition to visual graphic products, ArcGIS also has the capability to output data in numerical formats. Any output dataset from a map algebraic model in ArcGIS can also produce a numerical attributes table. Table 4 shows the numerical data the author chose to export from the Juba model attributes table for each HA/DR decision.

Table 4. Juba's HA/DR locations (top three features for each decision displayed).

Attribute Table Output from Juba HA/DR GIS Models							
Feature	UTM (36N)	Latitude	Longitude	Dimensions (m)	Ares (Acres)	Center Elevation (m)	DZ Axis (deg magnetic)
Campsite 1	343295540552	4°53'20.18"N	31°35'12.38"E		0.60	467	
Campsite 2	342141539908	4°52'59.14"N	31°34'34.95"E		0.44	465	
Campsite 3	341075539670	4°52'51.32"N	31°34'00.39"E		0.76	467	
Food Distro 1	343126540446	4°53'16.71"N	31°35'06.89"E		0.14	468	
Food Distro 2	342190539771	4°52'54.67"N	31°34'36.56"E		0.16	461	
Food Distro 3	341148341148	4°52'46.40"N	31°34'02.74"E		0.08	469	
Landing Zone 1	343252540616	4°53'22.25"N	31°35'10.97"E	100x100	0.23	469	
Landing Zone 2	341986539963	4°53'00.91"N	31°34'29.94"E	166x253	1.00	468	
Landing Zone 3	341411539531	4°52'46.80"N	31°34'11.30"E	239x480	2.45	467	
Drop Zone 1	343035538993	4°52'29.41"N	31°35'04.04"E	460x1049	11.10	464	187/007
Drop Zone 2	340215539221	4°52'36.62"N	31°33'32.50"E	600x1062	15.40	471	122/302
Drop Zone 3	339904537371	4°51'36.37"N	31°33'22.53"E	666x1200	18.30	505	095/275

Only vector datasets can produce numerical data in ArcGIS. An easy conversion back to a vector dataset enabled the attributes table that contains numerical data such as the location and area of each output point, line, or polygon. End users without access to a GIS system, such as pilots or aid workers out in the field, may need numerical data to perform their HA/DR tasks.

The overall lesson from the Juba validation was that even through partially developed GEOINT data within an AOI such as Juba, GIS processes still support timely, better-informed decisions in disaster-prone areas. Working through GIS-based modeling, extracted from Haiti's AARs and GIS literature, validated how GIS models produce graphic and numerical outputs that directly support the key HA/DR decisions. Without GEOINT data and GIS tools, graphic and numerical products referenced to geographic locations could not exist. Without these GEOINT products decision-making suffers because the information is less accurate. For example, the author had never visited South Sudan and had no initial understanding of Juba's complex HA/DR environment. Through unclassified datasets and the powerful ArcGIS software, the author made predictions in a few hours that in optimum conditions might take someone on the ground days or weeks to predict with paper maps. Thanks to baseline GEOINT data and well-designed GIS models, future planners can observe changing HA/DR conditions and make timely recommendations to decision-makers in the first seventy-two hours following a disaster.

An important lesson to highlight from the Juba analysis is the impact of outdated imagery. Figure 12 clearly depicts the changes in Juba's urban environment and its impact on the HA/DR decisions.

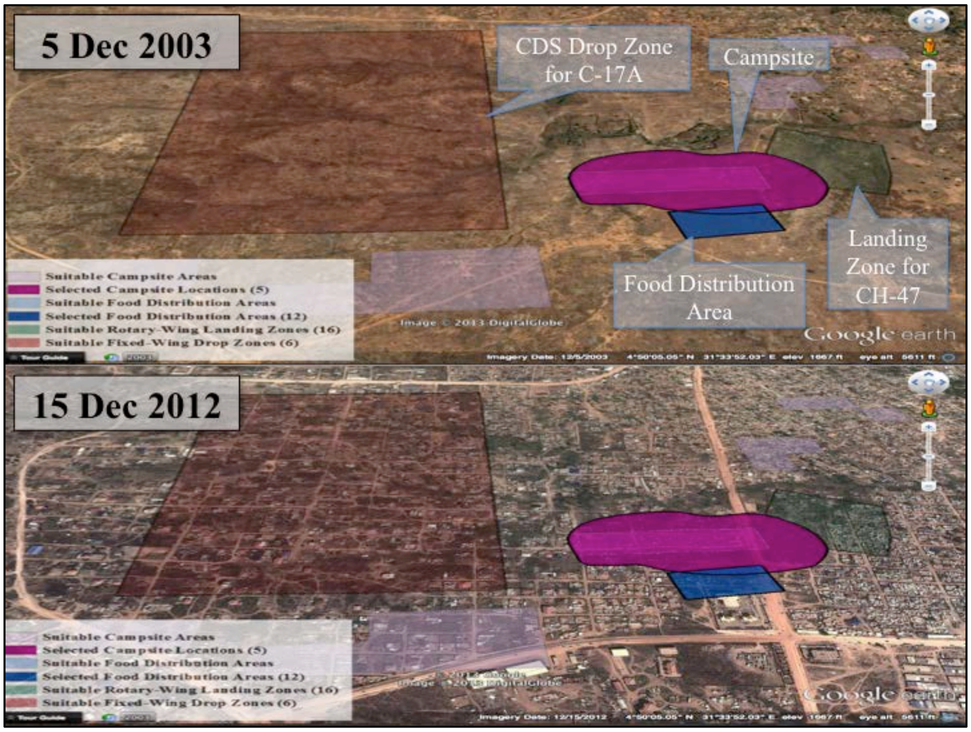

Figure 12. Comparison graphic showing Juba's urbanization between 2003 and 2012.

The author used 2005 data to perform GIS analysis in this project. The image closely matches the 2003 historical imagery on Google Earth®. Opening the Juba COP in Google Earth®, powered by current road datasets and imagery, quickly revealed this lesson. As predicted, Juba's landscape had changed significantly between 2005 and 2013 because of unprecedented population growth. Since the author purposely used LeadDog™ datasets and IKONOS™ imagery between five and seven years old, the GIS model produced some invalid results. In an actual HA/DR scenario, the fidelity and amount of data will improve as ISR assets focus collection on the AOI. The ISR focus also resolves issues with data currency. Even in the Juba scenario there was commercial imagery available from 2013 to alleviate the problems highlighted with outdated GIBCO and

WARP data. However, as one can presume from the previous Haiti study, this is a double-edged sword. Like a lack of GEOINT data, an abundance of new datasets can also clutter decision-making. If mismanaged, GEOINT data, current or outdated, can overload GIS systems and muddle planner priorities, ultimately adding more complexity to the HA/DR system.

To sum up the process used to validate the utility of GIS-models, the author set an AOI for Juba, broke the HA/DR problem into three separate parts defined by requirements and parameters, and produced verifiable model results. The model results easily produced a COP, shareable across whole-of-government through common GIS file extensions. The comparison using GEOINT data and GIS tools validated what was true in Haiti. GEOINT solutions to common HA/DR problems enhance decision-making.

CONCLUSION

Analytical requirements vary between different types of military missions and even between different types of HA/DR operations. However, common to all types of military planning is the growing role of GEOINT in providing information and analysis to support timely decision-making. HA/DR missions are exceptional because millions of human lives are at stake in the immediate aftermath of a natural disaster. Thus, the research focused on HA/DR operations immediately following earthquakes to properly examine the role of GEOINT support on decision-making. Considering the time available and accuracy required, only systemic processes can link the rich data within rapidly changing, complex HA/DR environments to operational decisions. Such decisions directly affect human lives, must be made early, and require GEOINT for accuracy. Natural disasters will certainly happen again and their HA/DR environments will be complex. Cluttered by uncertainty and chaos, HA/DR requires detailed planning and informed decisions to gain the support of the affected population by providing aid to the survivors. Faced with the context of a massive problem set, John Boyd’s key concepts helped conceptualize a timely approach to GIS-based modeling. Following Boyd's concepts help transform raw GEOINT data into useful support information for HA/DR decision-makers.

Three logistical decisions commonly emerge during HA/DR operations: selection of campsites, food DPs, LZs and DZs. First, the undirected and unplanned movement of displaced survivors drives the need to select campsites selection during HA/DR operations. Second, responders always must distribute food and medical assistance, which means they must designate distribution points. Third, since natural disasters damage and disrupt supply hubs, the responders must select alternate or additional LZs and DZs to deliver supplies. The research showed HA/DR to be logistics-heavy operations that require a holistic view from the outset of the disaster. The holistic view is needed because movement of people and resources is always the first priority. The Haiti case study revealed that GEOINT is the fastest way to gain a holistic view for logistical decisions immediately following a natural disaster.

The Haiti study confirmed that doctrine today, four years past the 2010 earthquake, does not explicitly link GEOINT support to the three logistical decisions. Advances in technology have created opportunities through rapid GEOINT growth for better-informed decision-making. However, joint doctrine only addresses the technical requirements rather than the planning considerations needed for a planner to exploit GEOINT. The doctrine needs guidance that tells the planners how use GEOINT through GIS to support decision-making. There specifically needs to be a conceptual framework (e.g., figure 6) so planners understand the GEOINT requirements and parameters supported by GIS-based models. The doctrine should also convey the role GEOINT plays in developing a comprehensive picture of the HA/DR environment through production of GIS-based COPs. Planners should share COPs on unclassified domains as much as possible, especially in HA/DR. The biggest COP challenge is not its design. The challenge has always been sharing it on a medium where the people that need to see it have immediate seamless access. In addition, GEOINT doctrine should catch up to the GIS models enabled by advances in the technology such as SRTM and LIDAR. Since GIS-based modeling is a shared responsibility between the planner and GIS analyst, doctrine should indicate what elements feed into GIS models. Elements of the GEOINT-based solution include requirements, parameters, datasets, spatial analysis tools, and ISR collection priorities.

The Haiti study also exposed an underlining HA/DR revelation. That is, speed is more important than efficiency in the first seventy-two hours of a HA/DR operation. Within the first three days displaced survivors require the most assistance. Knowing that speed is most vital in the response, the Haiti study exposed several challenges OUR planners faced to support operational decisions using GEOINT. The biggest immediate challenge was getting high fidelity GEOINT data because the earthquake destroyed much of Haiti's baseline data. Collecting and managing current GEOINT at the right time across the world will always be a challenge. Initially in Haiti, an overwhelming flow of disaster related humanitarian impeded baseline GEOINT data flow. Commercial vendors, military ISR assets, and mobile-enabled crowd-sourcing quickly brought current GEOINT datasets for the Port-au-Prince AOI. However, the time needed to filter, share, and actually use the GEOINT data delayed its use. Using decision requirements, planners data mined the GEOINT datasets to populate geodatabases. In future HA/DR, filtering the GEOINT data and prepping geodatabases can take place immediately after the disaster through refined geospatial metadata. In other types of natural disasters, planners can prepare some of the data leading up to the disaster. For example, for tsunamis, typhoons, and hurricanes, meteorologists often predict when these disasters will make landfall. Thus, planners can gather baseline GEOINT data and establish a planning timeline for the aftermath before the disaster strikes.

To leverage GEOINT support for timely decisions, OUR planners took deliberate steps once JTF-Haiti stood up to sort out the mess using GEOINT. Future planners will need to follow a similar process because they will face a similar set of challenges. First, planners translated the survivor needs, which quickly became the JTF-Haiti commander's priorities, into geospatial support requirements. Collection assets gathered any missing GEOINT datasets. Airborne and space-based ISR, to include LIDAR, adequately fulfilled the information requirements. Second, planners selected the relevant data within the datasets to populate geodatabases for the AOI. Third, based off the requirements and geodatabase information available, planners designed GIS models that used spatial analysis tools. Lastly, the outputs of the GIS models fed into GIS-based COPs. COPs were the best method to share the information with a variety of stakeholders and decision-makers across whole-of-government. This was an important step in the information age because interagency coordination and collaboration with the IC will always be necessary in HA/DR operations.

Lessons from the Haiti study and proper application of existing doctrine suggests a solution. The solution is an iterative process using GEOINT and GIS tools (e.g., figure 5). Planners should address all steps in the model when communicating with a GIS analyst if the geospatial analysis required is beyond their level of training. The author used the hypothetical great earthquake scenario based in South Sudan to validate Haiti's lessons, while further testing the GIS-based model with real-world GEOINT and ArcGIS 10.2. The validation showed how a planner can apply spatial analysis tools to model the individual HA/DR decisions, and how to the results can be seamlessly shared via a Cloud-based COP or common file format such as Google Earth®.

An unintended, yet important lesson was the potential impact of outdated GEOINT data, extracted during the Juba analysis. Like any decision with outdated information, old GEOINT data will produce an impoverished GEOINT solution. Those that favor paper maps over GIS-based visualization should understand that paper maps are only as current as the GEOINT imagery at the time of their production. Therefore, paper maps lag decades behind GIS maps because of printing, cost, and distribution challenges. Because of this, even outdated GEOINT datasets may remain more accurate than traditional paper methods. Knowing this, planners need to continuously evaluate data currency and prioritize information requirements appropriately for new collection.

Two areas arose beyond the scope of the research project. First, future research should examine the role of GEOINT and GIS to support decisions in a range of other military operations. There are many ways to leverage GEOINT-based solutions outside of HA/DR. Studying military missions in permissive and hostile operational environments will highlight other types of decisions that require GEOINT support. Second, future research should examine the role of different GIS. While ArcGIS 10.2 is a capable GIS that allows real-time data layering, fusing, and sharing, other GIS exist for specialized missions such as aviation. For instance, air planners use FalconView®, which uses many of the same imagery and datasets as ArcMap®. Modeling decisions in FalconView® differs from modeling decisions in ArcMap®. Planners should understand the requirements common to both, in order to perform the analysis themselves or to request a GIS analyst to perform the analysis for them. The capabilities of geographical information system tools and the availability of geospatial information data will certainly continue to grow. Military planners currently do not appreciate the power of these tools and are not able to guide their use by skilled analysts. Continued reliance on outdated data and processes will undoubtedly lead to poorer military decisions.

APPENDIX A: HAITI HA/DR COP SHARED VIA AN ADOBE GEOPDF® FILE

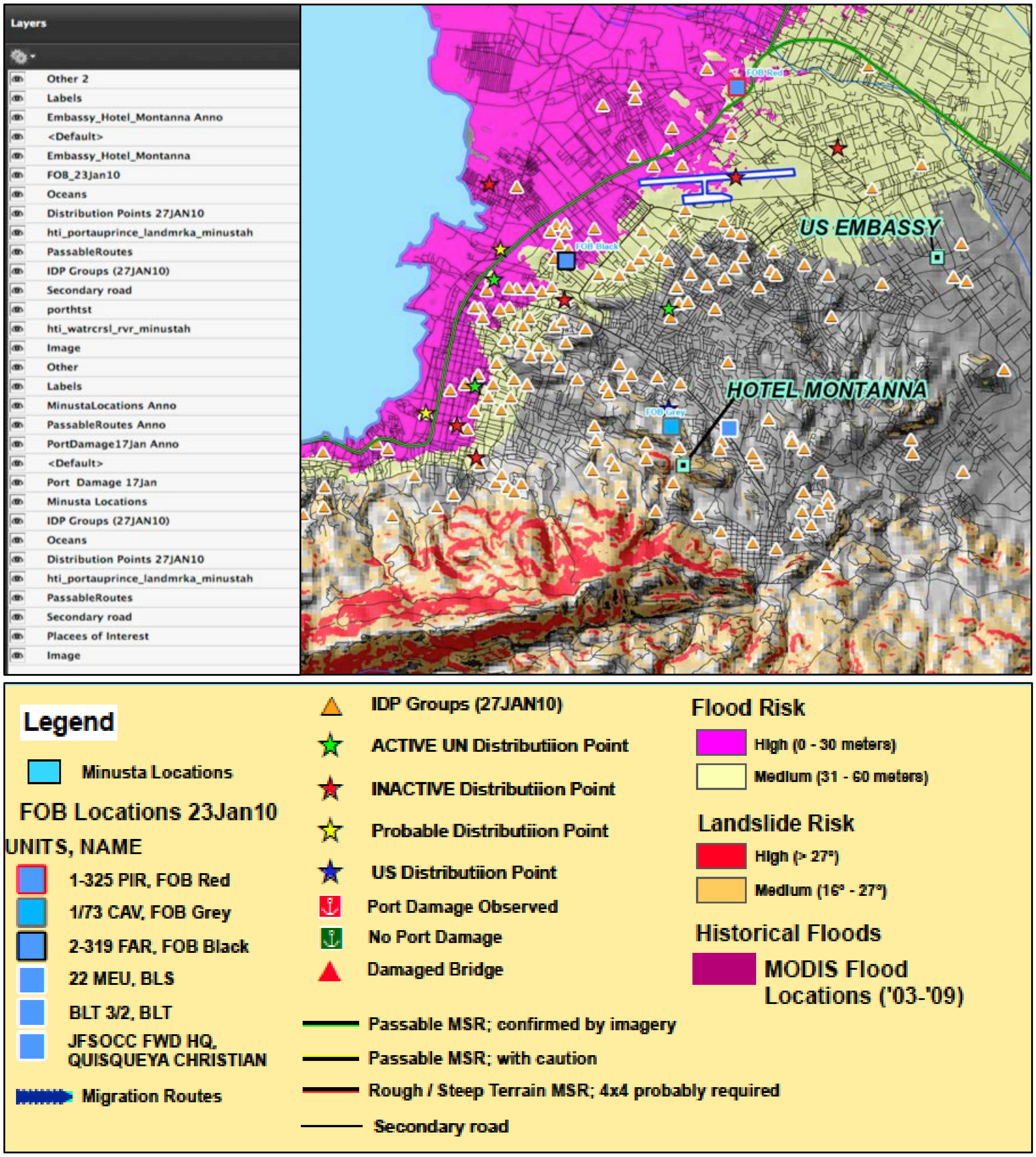

Figure 13. JTF-Haiti (27 Jan 10): DPs, IDP groups, flood and landslide risks.

Source: Data from National-Geospatial Intelligence Agency, "Haiti Distribution Points, Internally Displaced Persons, Flood and Landslide Risks" (Adobe GeoPDF®, National-Geospatial Intelligence Agency (JTF-H), Port-au-Prince, Haiti, January 27, 2010).

APPENDIX B: COMMON AND FUNDAMENTAL OPERATIONAL DATASETS

Table 5. IASC guidelines for CODs in disaster preparedness and response

Dataset	Recommended Governance	Mandatory Data Characteristics
Humanitarian Profile (disaggregated by admin level and populated place)	- Guardian: OCHA - Sponsor: OCHA - Source: Government, Assessments, UNHCR, IOM	- Internally Displaced[17] - Non-displaced affected - Host family/resident community affected - Refugee[18] - Dead - Injured - Missing
Population Statistics	- Guardian: OCHA - Sponsor: OCHA,UNFPA (Other potential sponsors could include UNDP, Government agencies or INGOs) - Source: Government	- Total population by admin level (Individuals) -Total population by admin level (Number of Households) - Age - Sex - Average family size by admin level - Unique identifier
Administrative Boundaries (Geographic) admin level 1 admin level 2 admin level 3 admin level 4	- Guardian: OCHA - Sponsor: OCHA (Other potential sponsors could include UNDP, Government agencies or INGOs) - Source: Government	- Unique identifier (P-Code) - Name
Populated Places (Geographic)	- Guardian: OCHA - Sponsor: OCHA, (Other potential sponsors could include UNDP, Government agencies or INGOs) - Source: Government	- Unique identifier (P-Code) - Names - Size classification - Population statistics - Status if capital of administrative division - Type (Village, spontaneous settlement, collective center, planned settlement)
Transportation Network (Geographic)	- Guardian: OCHA -Sponsor: Logistic Cluster -Source: Government	- Roads (Classified by size) - Railways - Airports/helipads - Seaports
Hydrology (Geographic)	- Guardian: OCHA - Sponsor: OCHA (Other potential sponsors could include UNDP, Government agencies or INGOs) - Source: Government	- Rivers (Classified by size) - Water bodies
Hypsography (Geographic)	- Guardian: OCHA - Sponsor: UNOSAT - Source: Remote sensing, Government	-Elevation -Resolution

Source: "Guidelines for Common Operational Datasets (CODs) in Disaster Preparedness and Response" (Inter-Agency Standing Committee (IASC), November 1, 2010), http://cod.humanitarianresponse.info/about-codfod (accessed August 14, 2013).

APPENDIX C: GIBCO DATASETS AVAILABLE FROM NGA FOR SOUTH SUDAN

Table 6. Sudan “Country” GIBCO DVD inventory

Category	Sudan GIBCO Data Set	DVD Number
Charts	3D Scenes	1
Charts	Blended Imagery	1
Charts	City Graphics	1
Charts	GeoPDF® Files	7
Charts	GIBCO/NEO Site Specific Data (including Product Listing)	7
Charts	Hydrographic Charts	1
Charts	Image City Maps	1
Charts	JOG - 250K	1
Charts	Planning Charts (GNC, ONC, JNC, Reference Maps, etc.)	1
Charts	Russian MIM - 100K	1
Charts	Russian MIM - 200K	1
Charts	TLM - 100K	1
Charts	TLM - 50K	1
Charts	TPC - 500K	1
Imagery	CIB® - 1 Meter (Order GIBUXSUDAN1MCIB, NSN# 7644015859386)	---
Imagery	CIB® - 5 Meter	2, 3
Imagery	15 meter NaturalVue™	5
Imagery	DigitalGlobe® CitySphere™	3, 4
Imagery	DigitalGlobe® QuickBird™	3, 4
Imagery	DigitalGlobe® WorldView-1™	3, 4
Imagery	GeoEye® IKONOS™	3, 4
Vectors	Digital Nautical Charts	1
Vectors	LeadDog™ Vector Data Sets	6
Vectors	NAVTEQ® NavStreets™ Vector Data Sets	6
Vectors	Other Vector Data Sets	6
Vectors	Stereo Airfields	1
Vectors	Urban Feature Data	6
Vectors	Vectors - 250K	1
Other	AFMIC Medical Data Files	1
Other	Army Geospatial Center E-Index GeoPDF® Files	7
Other	Army Geospatial Center Engineering Route Studies and Shapefiles	1
Other	Army Geospatial Center Manual of Environmental Effects	1
Other	Army Geospatial Center Military Capabilities Studies	1
Other	Army Geospatial Center Urban Tactical Planner ArcGIS Projects and Shapefiles	1
Other	Army Geospatial Center Urban Tactical Planner TerraExplorer® Fly-Thru Files	1
Other	Army Geospatial Center Water Resources	1
Other	CIA Factbook	1
Other	DAFIF®	1
Other	U.S. Department of State F77 Report	1
Other	DTED Levels 0, 1, 2	4
Other	DVOF	1
Other	Geonames	1
Other	HarborView™ Harbor Scene Visualization	6
Other	Marine Corps Intelligence Activity Cultural Info Files	1
Other	Metadata	1, 2
Other	SRTMFDTED Levels 1 and 2	7

Source: Adapted from “Sudan Country” GIBCO DVD #1.

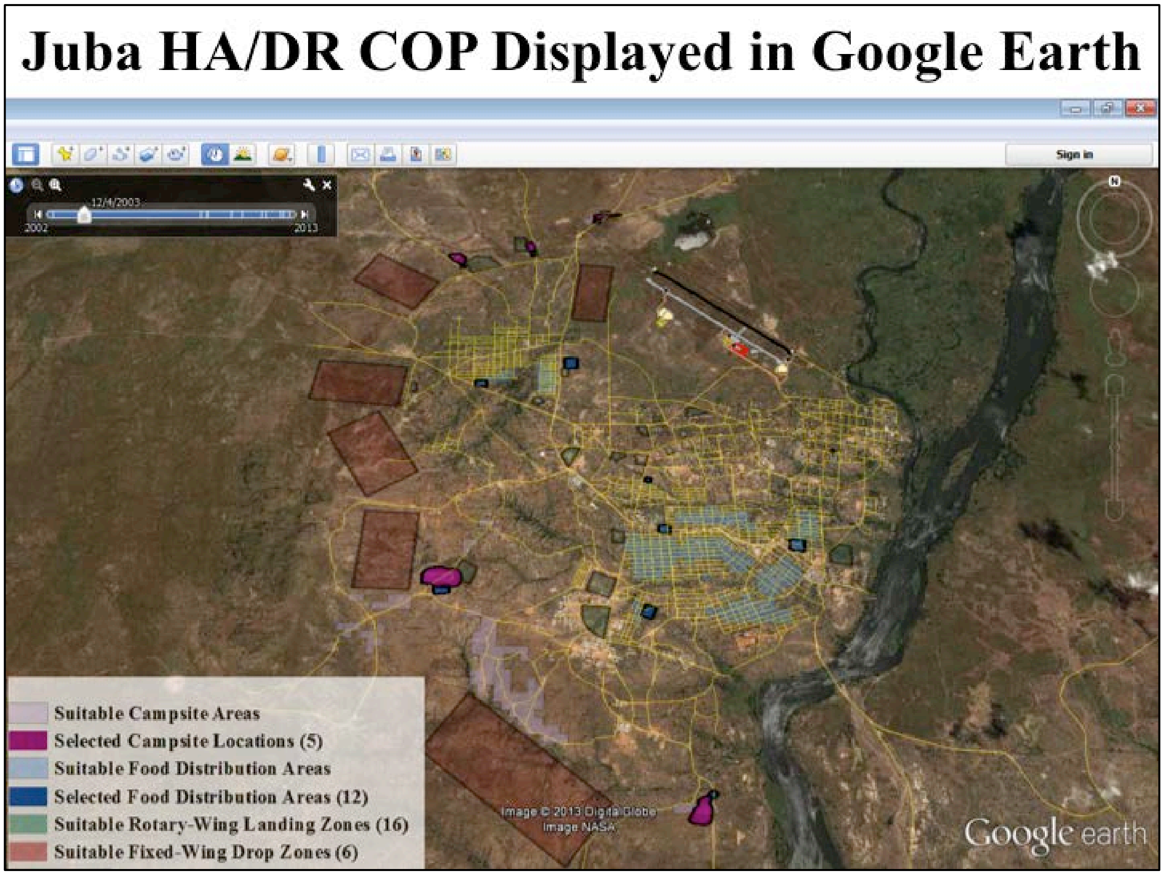

Figure 14. Juba HA/DR COP displayed in Google Earth®

Note: The planner can share the entire COP through one 2.5-megabyte KML file that requires a double mouse click to open.

APPENDIX E: GEOINT REFERENCE AIDS

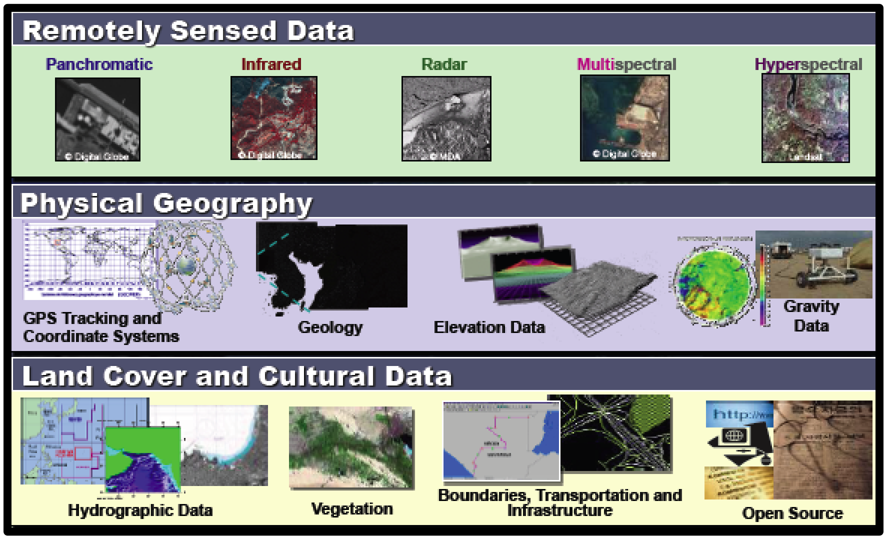

Figure 15. Overview of GEOINT data types.

Source: Ralph Erwin, "The Power of GEOINT" (PowerPoint Presentation, Fort Leavenworth, KS, September 2012).

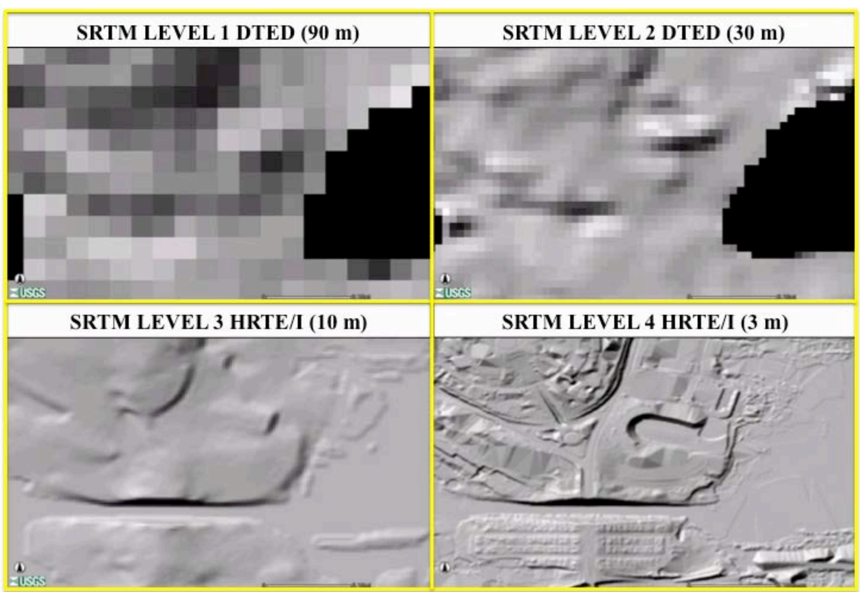

Figure 16. SRTM elevation data resolutions: DTED® and HRTE/I.

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